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THE AMERICAN UNIVERSITY IN CAIRO
SCHOOL OF SCIENCES AND ENGINEERING
ENVIRONMENTAL ENGINEERING DEPARTMENT

**DEVELOPING INDUSTRIAL RESOURCE
SUSTAINABILITY ROADMAP: CEMENT INDUSTRY
CASE STUDY**

By

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B.Sc. in Construction Engineering, 2008

A thesis submitted to the School of Science and Engineering in
partial fulfillment of the requirements for the degree of

Masters of Science in Environmental Engineering

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I would take this opportunity to thank my brother and sister dearly, for consistently helping and supporting me, both morally and physically. Their presence and overwhelming love never failed me.

Finally, I would like to thank my husband and my partner for his prayers, support and presence. He was always an encourager and was continuously there for me during this walk.

ABSTRACT

For proper implementation of sustainability, two dimensions need to be taken into consideration, resource conservation and pollution prevention. Compromising on any of the two would mean that future generations are deprived of their ability to meet their needs. Since resources are the building blocks of all economies, and a clean pollution free environment benefits the general welfare of the society, the economy and social part are automatically taken care of. The goals of resource sustainability were realized in the following three stages:

1. **A roadmap** was developed to address the management and strategic requirement for successful implementation of resource and environmental sustainability. Its components comprise inputs of binding regulations, internal organizational limitations, external concerns and the needs and expectations of involved parties. Business owners receive all the stakeholders' inputs and incorporate them into a sustainability management system. The management system is then used to implement an appropriate action plan corresponding to the goals and objectives of the SMS. The last step of the roadmap is a performance analysis to measure alignment with the cradle to cradle/ Industrial ecology goals and objectives previously set. One of the following two statuses is assigned in the evaluation:

1. A compliance status indicates a basic level of cradle to cradle
2. A beyond compliance status indicates that the facility was able to achieve the goals of cradle to cradle, while creating profit out of it.

1. **A sustainability management system (SMS)** was developed as a major requirement for success of the roadmap. The first step towards a successful management system is a policy commitment to resource sustainability. In the mean time, baseline conditions are measured and used in the strategic resource sustainability planning phase to:
 - a) Determine a resource sustainability strategy.
 - b) Set SMART goals and strategic objectives.
 - c) Design support tools and performance measures.
 - d) Establish strategic initiatives and action plans.
2. **A model** developing technique is proposed using a life cycle approach to measure the extent to which resource and environmental sustainability can be attainable. To demonstrate the idea, an evaluation tool, The Cement Resource and Emissions Monitoring Application was developed as a support tool, performance Measure and performance analysis for the cement industry. The model allows for the application of three industrial ecology techniques requiring changes in conventional ways in order to reduce emissions and raw materials.

A case study was applied on Lafarge to demonstrate possible reductions in emissions and raw materials. Results showed that substituting fuel oil, natural gas and coke for rice straw resulted in a 36.5%, 28.2%, and 47.1 % drop in the total CO₂ emissions respectively. Another benefit of substitution included an avoided 6126 kg of NO_x emissions resulting if rice straw met its conventional fate, i.e. burned in the fields. It was also found that fuel substitution resulted in an avoided

3,000,000-5,000,000 kg of Sox emissions that would have normally been emitted as a result of fossil fuel burning and another 143,627 kg that would have occurred while burning rice in the fields. About 28,198,824 kg of CO that would have occurred as a result of field burning of rice straw was also possibly avoided.

The second industrial ecology principle applied, featured substituting clinker for other raw materials. A 50 % decrease in clinker, resulted in a 50 % decrease in the amount of required fuel and a 50% decrease in the amount of energy required for clinker production, assuming a linear relationship between energy requirement and amount of clinker. It also resulted in a consequent 31.7 % CO₂ reduction and a 50 % decrease in other emissions.

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ABBREVIATIONS

As	Arsenic
BC	Beyond Compliance
BC	Black Carbon
BS OHSAS	British Standards Occupational Health and Safety Management Systems
C2C	Cradle to Cradle
Cd	Cadmium
CESD	Commissioner of the Environment and Sustainable Development
CH ₄	Methane
CKD	Cement Kiln Dust
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
CP	Cleaner Production
CP-EMS	Cleaner Production Environmental Management System
CREMA	Cement Resource and Emissions Monitoring Application
Cr	Chromium
CSD	Commission on Sustainable Development
Cu	Copper
DFO	Design for environment
EAC	Environmental Audit Committee
EC	European Commission
EF	Emission Factor
EHS	Environmental, Health and Safety
EMEP/EEA	European Monitoring and Evaluation Program (monitoring and evaluation of long range transmission of air pollution)/European Environment Agency
EMS	Environmental Management System
EPR	Extended Producer Responsibility
g/GJ	Gram Per Gigajoule
g/t	Gram Per Tonne
GJ/m ³	Gigajoules Per Cubic Meter
GJ/t	Gigajoules Per Tonne
GJ/yr	Gigajoules Per Year
GWPs	Global Warming Potentials
Hg	Mercury
IE	Industrial Ecology
IPCC	Intergovernmental Panel on Climate Change
IS	industrial symbiosis
ISO	The International Organization for Standardization
JPOI	Johannesburg Plan of Implementation
Kg/GJ	Kilogram Per Gigajoule
LCA	Life Cycle Assessment
MBDC, LLC	McDonough Braungart Design Chemistry limited liability company

MFA	Material Flow Analysis
MEPR	Modified Extended Producer Responsibility
mg/GJ	Milligram Per Gigajoule
µg/GJ	Microgram Per Gigajoule
NCV	Net Calorific Value
ng I-TEQ/GJ	Nano grams International Toxic Equivalent
Ni	Nickel
NMVOC	Non-Methane Volatile Organic Compound
NO _x	Nitrogen Oxides
N ₂ O	Nitrous Oxide
PCDD/F	Polychlorinated Dibenzodioxins/ Dibenzofurans
Pb	Lead
PM	Particulate Matter
PM-10	Particulate Matter of Size of 10 Microns in diameter or Smaller
PM-2.5	Particulate Matter of Size of 2.5 Microns in diameter or Smaller
Se	Selenium
SMS	sustainability management system
SMART	Specific, Measurable, Attainable, Realistic, Timely goal
SO _x	Sulfur Oxides
TBL	Triple Bottom Line
TSP	Total Suspended Particulates
UN	United Nations
UNCED	UN conference on Environment and Development
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
WCED	World Commission on the Environment and Development
WBCSD	World Business Council for Sustainable Development
Zn	Zinc

CHAPTER 1 : INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1. Pre-sustainability: growing concern for the environment

Progressive increases in consumer demands along with aggressive industrial consumption, led the world to proximate resource depletion, weather changes, soil and air degradation and water quality deterioration. The environmental tax of the “consumer type” lifestyle remained long unknown before being accentuated to the public recognition.

The concern for environmental protection started as a movement response to the industrial revolution and was manifested in different ways in the different parts of the world through different times. (Urbinate, 1994) At the time however, most of the deliberations undergone addressed only one dimension of sustainability, namely the environment, ignoring other important focuses.

1.2. Emerging of sustainability

The beginnings of sustainable development occurred in the period in between 1972 and 1992 during which several dedicated conferences were held. The first global scale formal event carried out to discuss sustainability, was the United Nations (UN) conference on the Human Environment held in Stockholm in 1972. Since then, the reach of sustainable development governance has expanded considerably at local, national, regional and international levels (Drexhage & Murphy, 2010).

The conference resulted in numerous conclusions relating to sustainability and led to the establishment of a number of protection agencies around the world as well as the well known UN Environment Programme, UNEP (Drexhage & Murphy, 2010).

The implementation of the recommendations of the Stockholm convention in 1980 resulted in several partnerships that further resulted in an enhancement in conservation policies and progress related to other sustainability issues.

In 1983, the UN assembled with the World Commission on the Environment and Development (WCED) in a convention gathering representatives from all over the world, with the intention of discussing the quickly degrading environment and the likely economic and social development costs.

The term sustainable development sprouted in Our Common Future report released by the WCED in 1987 (Drexhage & Murphy, 2010). The report, also known as the Brundtland report, expressed, for the first time, the need for the integration of “economic development”, “natural resources management and protection” and “social equity”. The latter concept later become central in framing the discussions at the 1992 United Nations Conference on Environment and Development (UNCED), also known as the Earth Summit. The report also introduced the worldwide renowned definition of sustainable development: “a development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs” (Drexhage & Murphy, 2010).

The Brundtland definition of sustainability proved effective over the years and still upholds to the present time

After the report was accepted by the United Nations (UN) General Assembly, sustainable development gained political importance, driving leaders to lay the foundations of sustainable development at the Rio Summit or Earth Summit, the UN conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil in 1992 (Drexhage &

Murphy, 2010). The conference yielded the United Nations Framework Convention on Climate Change (UNFCCC), an international treaty to reduce greenhouse gas concentrations in the atmosphere to an acceptable degree that would not contribute negatively to the climate.

In 1993 the General Assembly established the Commission on Sustainable Development (CSD), as the UN high level political body entrusted with the monitoring and promotion of the implementation of the Rio outcomes, including Agenda 21.

The 2002 World Summit on Sustainable Development advance the mainstreaming of the three dimensions of sustainable development in development policies at all levels through the adoption of the Johannesburg Plan of Implementation (JPOI).

Trailing the same path, with intentions of discussing climate change, other conventions followed years after, most important of which are the Kyoto, Japan in 1997 and the Copenhagen, Denmark in 2009.

Realizing the need for economic growth, a need to protect the environment, and the need for policies to balance between both, many countries such as Finland, Sweden and Norway undertook policies to reduce environmental degradation.

In 2012 at the Rio+20 Conference, the international community decided to establish a High-level Political Forum on Sustainable Development to subsequently replace the Commission on Sustainable Development. The High-level Political Forum on Sustainable Development held its first meeting on 24 September 2013 (Processes & UN System).

The timeline in Figure 1-1 illustrates the evolution of sustainable development explained above.

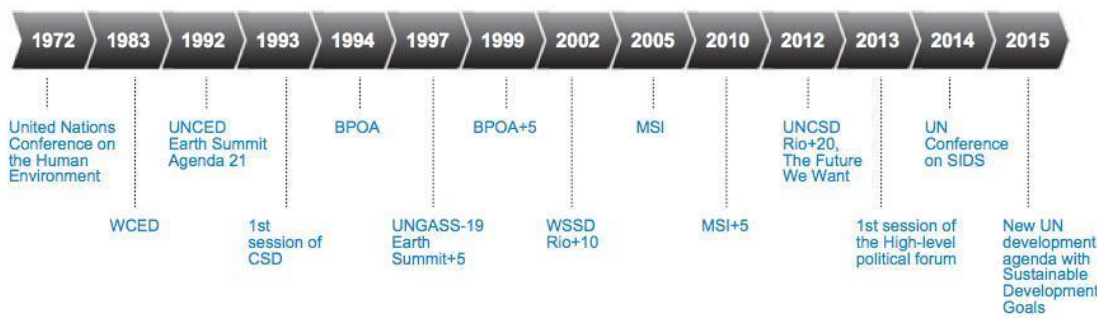


Figure 1-1: Evolution of SD

Source: (Processes & UN System)

1.3. The principles of sustainability

A clear definition of sustainability, satisfying to all, proved to be a hard, if not an altogether an impossible task. It is therefore sometimes necessary that one goes back to the origins of the word to grasp the real meaning. (El-Haggar, 2007)

The word sustainability is a derivative of the Latin word “sustinere”, where “sus” means up and tinire means to hold, implying the need to maintain. (El-Haggar, 2015)

Despite the elusiveness in meaning, three major attitudes seem to be well accepted and are spontaneously attributed to sustainability. The first recognizes the need for reducing poverty amongst the world’s neediest and the importance of reducing or ideally eliminating impacts on future generations. The second stresses on accounting for long term effects of our actions “where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation” (Rio Declaration, n.d). The last of the three combines the previous two and is the most commonly reiterated one, which stresses on the need to provide an idealized development vision maintaining a proper equilibrium

between individuals, society, the economy and the regenerative capacity of the planet's life-supporting ecosystems, depicted in figure 1-2.

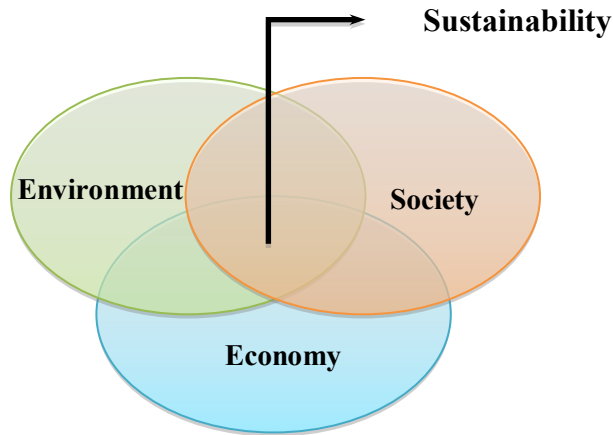


Figure 1-2: Spheres of Sustainability

For these principles to be brought to reality, modifications need to be applied to the current systems implementing paradigms, values, visions, policies, education and training, indicators, facilitators, and formula to promote, implement, monitor, and quantify the movement towards sustainability. (El-Haggar, 2007)

1.4. Research Motivation

The research was motivated by three major factors, these being the challenges facing sustainable development, the lack of focus on resource sustainability and the unavailability of standard ways to monitor the resource performance, detailed in the section below.

1.4.1. Challenges facing sustainable development

Although countries, communities and individuals have committed to promoting

sustainable development, implementing the perfect balance between its three pillars has proven to be considerably challenging.

The challenge is particularly pronounced in the presence of technological advances and an unprecedented level of economic growth.

A major obstacle identified by involved parties, was the ability of accommodating for the emerging economic growth without causing harm to the environment, especially with resource depletion. At the same time, complying to the UN identified need for bringing human and environmental welfare to equilibrium in the developing countries led to the shifting of the prevalent economic growth concept to new sustainable development criteria, defined in the Bruntland commission report. (Heinberg, 2007)

1.5. Resource Depletion: A recited challenge facing sustainable Development

The planet witnessed a “four times” increase in the population during the last century, an unprecedented 20-fold boost in economic production and a significantly elevated demand for natural resources (Steer, 2013). This was essentially the case for minerals, metals, biomass, land, clean air, weather, and ecosystem services. (Steer, 2013). As a result, natural resources are seriously endangered.

1.5.1. Materials Consumption

While the use and transforming of resources enhances scientific, technological and economical advancement (UNEP, 2011), the current rate at which resources are consumed is expected to limit the ability of future generations and the developing communities from fairly accessing the limited available resources. (EC, 2015)

According to UNEP report, an annual consumption of 60 billion tones of raw materials is

expected by the year 2005, that is an approximately double material extraction in only 10 years.

Surveys carried out by UNEP reported a 34, 27, 12, and 3.6 times increase in construction, mineral ores, fossil fuels and biomass mining respectively in the period between 1900 to 2005. This increase is illustrated in Figure 1-3 below. (UNEP, 2011)

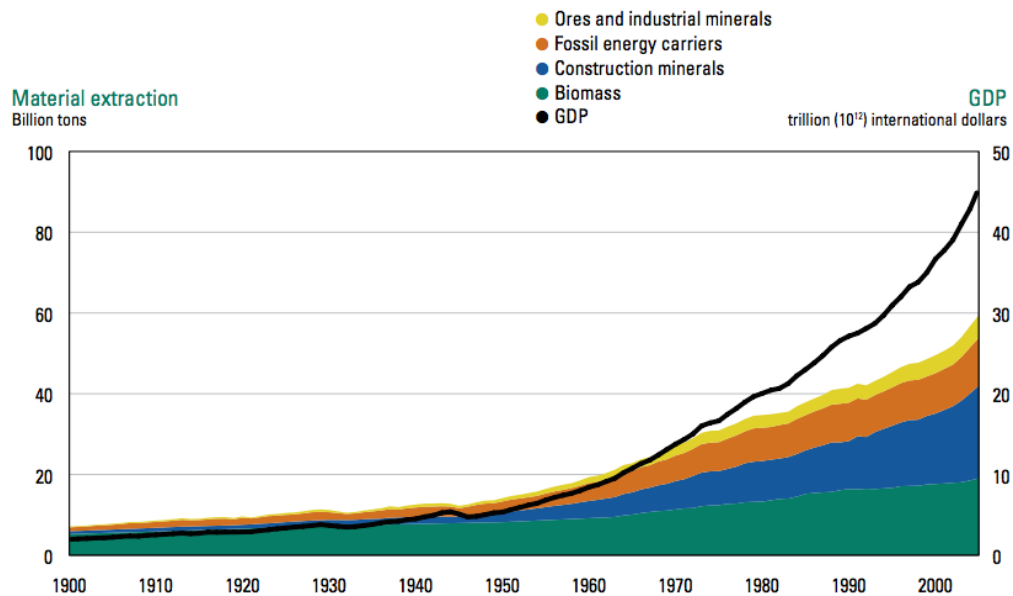


Figure 1-3: Global material extraction in billion tons, 1900–2005

Source: UNEP, 2011

It is also expected that the total consumption would go up to an estimated annual 140 billion tons of minerals, ores, fossil fuels and biomass, approximately three times its current by the year 2050. (UNEP, 2011)

1.5.2. Risk of Depletion

Should the current resource consumption continue the same exhaustive trend, severe harms can occur surpassing the possible tolerance of the environment. The severity of the risk increases even more, as the developing world reaches a comparable resource

consumption trend to that of the developed countries.

Table 1-1: Current Supply risk index for Chemical element groups that are of economic value

Element or element group	Symbol	Relative supply risk index	Leading producer	Top reserve holder
rare earth elements	REE	9.5	China	China
tungsten	W	9.5	China	China
antimony	Sb	9.0	China	China
bismuth	Bi	9.0	China	China
molybdenum	Mo	8.6	China	China
strontium	Sr	8.6	China	China
mercury	Hg	8.6	China	Mexico
barium	Ba	8.1	China	China
carbon (graphite)	C	8.1	China	China
beryllium	Be	8.1	USA	Unknown
germanium	Ge	8.1	China	Unknown
niobium	Nb	7.6	Brazil	Brazil
platinum group elements	PGE	7.6	South Africa	South Africa
cobalt	Co	7.6	DRC	DRC
thorium	Th	7.6	India	USA
indium	In	7.6	China	Unknown
gallium	Ga	7.6	China	Unknown
arsenic	As	7.6	China	Unknown
magnesium	Mg	7.1	China	Russia
tantalum	Ta	7.1	Brazil	Brazil
selenium	Se	7.1	Japan	Russia
cadmium	Cd	6.7	China	India
lithium	Li	6.7	Australia	Chile
vanadium	V	6.7	South Africa	China
tin	Sn	6.7	China	China
fluorine	F	6.7	China	South Africa
silver	Ag	6.2	Mexico	Peru
chromium	Cr	6.2	South Africa	Kazakhstan
nickel	Ni	6.2	Russia	Australia
rhenium	Re	6.2	Chile	Chile
lead	Pb	6.2	China	Australia
carbon (diamond)	C	6.2	Russia	DRC
manganese	Mn	5.7	China	South Africa
gold	Au	5.7	China	Australia
uranium	U	5.7	Kazakhstan	Australia
zirconium	Zr	5.7	Australia	Australia
iron	Fe	5.2	China	Australia
titanium	Ti	4.8	Canada	China
aluminium	Al	4.8	Australia	Guinea
zinc	Zn	4.8	China	Australia
copper	Cu	4.3	Chile	Chile

Source: (Mineralsuk, n.d.)

1.5.3. Waste

In addition to the extensive use of resources, the currently recurring resource trend resulting from human actions constantly follows a “cradle-to-grave” pattern, shown in Figure 1-4. In a cradle-to-grave cycle, raw materials enter the manufacturing loop and

exit to a landfill as waste at the end-of-life (El-Haggar, 2007). According to a report carried out by MoLD in 2010, Egypt's total waste sums up to about 94, 936,530 tonnes as listed in Table 1-1 (Zaki, 2013). Most of the latter waste follows a cradle-to-grave pattern and is discharged of in open dumps and non-engineered landfills.

Table 1-2: Generated solid waste in Egypt, 2010

Waste Type	Generated Quantity (Tones)	Generated Quantity (%)
Municipal solid waste	13,806,269	15
Construction and demolition waste	41,748,603	44
Agricultural waste	30,000,000	32
Industrial waste	2,906,895	3
Medical waste	3,416,254	4
Waterway cleansing waste	3,058,509	3
Total	94,936,530	100

Source: *MoLD, Retrieved from Zaki, 2013*

For sustainability to be achieved, the cradle to grave trend needs to be eliminated from the conceptual and operational framework of societies and replaced with a closed loop that uses renewable resources and produces zero waste, also known as a cradle-to-cradle system. (EL-Haggar, 2007). This pattern is illustrated in Figure 1-5.

The cradle-to-cradle term is used to refer to a system where primary resources are turned into products and products are used as secondary resources for other products at the end of service life instead of being landfilled or incinerated.

Since sustainability cannot be achieved without paying attention to resources, using disposed matter, waste and emissions as byproducts or co-products is inevitable. (El-Haggar, 2007)

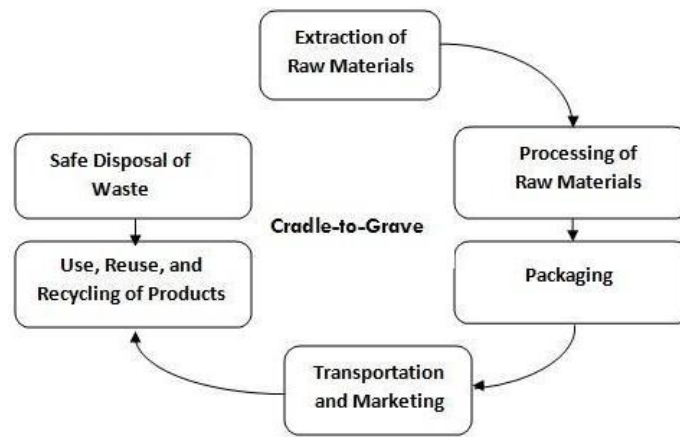


Figure 1-4: Cradle to Grave

Source: El-Haggar, 2007

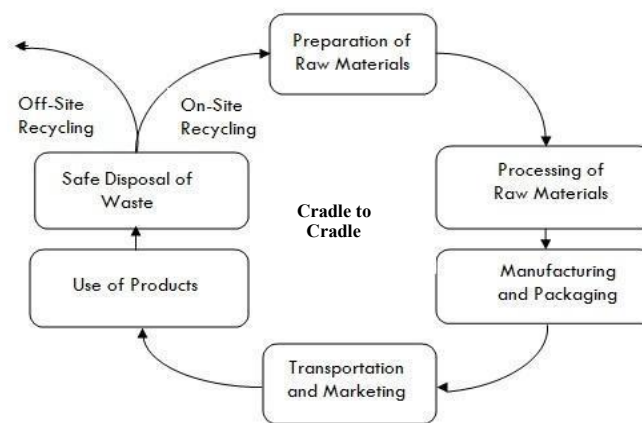


Figure 1-5: Cradle-to-Cradle

Source: El-Haggar, 2007

1.6. Research Objectives and Scope

This research aims at upgrading sustainable practices from designing for compliance to designing for beyond sustainability, with particular focus on industry. A simple roadmap is proposed to be adapted as a generic pathway to sustainability. The roadmap brainstorms and places different sustainability concepts together to form a path that is

believed to lead to sustainability. A sustainability management system (SMS) model is developed relying on the basic Environmental Management System (EMS) model, but with a focus on resource sustainability. Detailed objectives of this research are divided into two parts:

First Part:

- Investigate sustainability and its development.
- Research different concepts and approaches used in the quest for sustainability.
- Emphasize the challenges in the implementation of sustainability
- Develop an adaptive framework integrating cradle to cradle design, different sustainability concepts, stakeholders, performance measurements and continuous improvement (Roadmap).
- Develop a generic sustainability management system model grounded on cradle-to-cradle concepts to achieve optimum sustainability design.

Second Part:

- Establish a methodology to analyze industrial systems performance based on beyond sustainability with a focus on the cement industry.
- Develop a model to analyze the sustainability of the cement industry

This research essentially focuses on both environmental and resource health impacts of products, taking into account the environment, resources, energy and innovation in design.

1.7. Research Flow

Successfully implementing sustainability is a multifactorial challenge that combines both initializing and implementation of sustainability strategies.

This work intends to provide a roadmap along with rating criteria and several tools to provide a step forward towards practical implementation of sustainability. It also introduces cradle-to-cradle concept as a key driver of sustainability, which arguably allows for better incorporation of the social and environmental dimensions of sustainability.

Table 1-3 summarizes the organization of chapters and flow logic.

Table 1-3: Mapping Research Approach and Methodology

Basic Means	Stages	Outcomes/Establishment
Introduction	Introduction to the topic, Historical emerging of concept of sustainability, dimensions of sustainability, Establishing that there are challenges facing the implementation of sustainable development, identifying major challenges	<ul style="list-style-type: none">• Research Objectives and Scope• Research Flow
Literature Review	Different concepts in addressing challenges, How things were handled by others, current practices	<ul style="list-style-type: none">• Ambiguities in implementation• Need for different management systems• Need for strategic handling,• Room for research
Objectives		Hypothesis, Statement of research outcomes
Methodology		<ul style="list-style-type: none">• Roadmap to sustainability• Sustainability management system (SMS)• Case Study, Evaluation tool (Model)
Case Study		
Conclusion and Recommendations		

CHAPTER 2 : LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1. Mapping Different Sustainable Development Approaches: Economic, Social, Environmental and Regulatory Tactics

Being seen as an absolute necessity for the preservation of resources and the continuation of life, sustainable development principles have been undertaken by many segments at all levels of the society.

Different people have defined ways of achieving sustainability differently. Green economists for example propose that changes need to be applied to the market to compensate for past and current failures and regulations need to be imposed to accomplish ecological sustainability. (Pearce et al. 1989)

Reformers, realize the need for government intervention in pushing, controlling, taxing, targeting of research and disseminating of information to put businesses on the sustainability track. It also goes without saying, that political systems will need to feature changes in order to enhance democracy and participation.

Change advocates on the other hand, believe that a mix between of best practices, open-minded community leaders, and functional contribution of local businesses along with public willpower is essential to achieve sustainability. Others see a close link between environmental and socio-economic issues. The book “From Here to Sustainability: Politics in the Real World”, the authors communicate the opinion of 25 leading UK campaigning organizations, stating that ‘business as usual’ enhances unfairness, poverty, environmental deterioration and world imbalance. To overcome the latter, a ‘radical system reform’ is required where coordination between the government and society is implied in hopes of achieving ‘sustainable, accountable and equitable forms of

capitalism'. (Hopwood et. al, 2005)

2.2. Governance approaches to SD

Although almost all participants along supply chains have acknowledged the need for change, and despite the major innovations seen in realization of their goals, most governments are yet in the earlier phases of absorbing the efficient tactics and harmonized action for sustainable development. (Chai, 2009;2014). Despite the immaturity in Sustainable Development logic, several major developmental steps have been undertaken within different sectors in diverse individual walks including leadership, planning, implementation, monitoring and learning (Urama, 2014).

On a governmental level, some countries imposed sustainable development within their planning processes. (Chai, 2009;2014). This is the case for Canada's Commissioner of the Environment and Sustainable Development (CESD) (Justicecgcca, 2016) and UK's Environmental Audit Committee (EAC) ("Environmental audit committee," 2010).

Despite the influential role of governmental institutions in the walk towards sustainable development, many countries yet need to align their policies with sustainable decisions.

One essential but poorly addressed component of sustainable development is the monitoring and evaluation part, leaving quality control and feedback underdeveloped (Chai, 2009;2014). Monitoring plays an important role at all levels of the process, both on the micro scale for measuring progress of specific short term goals within a single stage and on the macro scale for the measuring of accomplishment of the final goals of sustainability. Monitoring on all scales delivers information on the status of accomplishment of the initiatives, for following up on progress in sustainable development strategy, economic, social and environmental status.

To ensure that performance results are an accurate measure for integrated sustainability, i.e. consistent with the mission of government, convenient to citizens and up to the public service quality standards, current performance evaluation practice must be made to be a participatory process.

2.3. Environmental approaches to SD

2.3.1. Cleaner Production

The expression Cleaner production (CP) was initiated and defined by the United Nations Environment Program (UNEP) to describe the process of sustainable production.

According to the agreed definition, cleaner production presented a process of “continuous application of an integrated, preventive environmental strategy to processes, products and services to increase eco-efficiency and reduce risks to humans and the environment” (UNEP, 1997). Cleaner production emphasizes the need to practice prevention rather than end-of-pipe treatment of arising environmental harms. Cleaner production also addresses the need to use resources in an efficient manner to avoid resulting pollution, consequently, improve the health, safety and result in an economic outcome. Cleaner production is a preventive approach to environmental management; It comprises eco-efficiency and pollution prevention techniques such as good housekeeping, implementation of process, environmental design of products in order to conserve natural resources such as water, energy and raw materials (El-Hagggar, 2007). Cleaner production can be successfully achieved when know-hows are properly implemented, technologies are improved and mindsets are changed.

Cleaner production addresses the production process in both theory and practice, taking into account all the life cycle stages of the products to prevent or minimize risks to

humans and to the environment. One pronounced benefit of cleaner production is the reduction in the production costs, which is achieved by the improvement of production efficiencies. If cleaner production is to be compared with end of pipe treatment, the main noticeable difference appears in the investment costs. End of pipe treatment almost always involves further investment while cleaner production creates value and involves the use of cleaner technologies. While cleaner production may be achieved using many different technologies, all aim at making the production cleaner, to minimize pollutants, waste and non-renewable resources used in the process.

People have lately become more particular about Zero pollution making it a hot topic proposed in many of the major sectors of economies, the main of which are industrial sectors, vehicles, construction and agriculture. In order to approach zero pollution in any of the latter sectors, it is necessary that all pollutants be eliminated from its effluent.

Waste / pollution elimination is a process that begins from raw material selection, includes recycling and product modifications and aims at preventing end of pipe treatment.

2.3.2. Cradle to cradle, green chemistry and Eco design

Cradle to cradle is a concept that looks at all activities undergone by humans, including all production and consumption provides nutrition for nature and industry. (“The cradle-to-cradle alternative,” 2003)

Cradle to cradle views poor design as the primary reason for the cradle to grave industrial pattern, rather than an inescapable trend that automatically follows consumption and economic activity.

Unlike conventional environmental protection concepts, that seek ways of making things “less bad”, cradle to cradle is more than simply reducing the harms of industrial activity. In conventional approaches for example, the best that can be done is to use energy and materials in a more efficient way. While this reduces the amount of harm, it does not eliminate the root cause. Recycling thought is one that has been extensively discussed in the sustainability concept. While it does allow for virgin resource conservation, it will eventually end up in a landfill where its components may turn to hazardous waste. (“The cradle-to-cradle alternative,” 2003)

Cradle-to-Cradle Certified Product Standard walks production processes through five evaluation categories, namely “material health, material reutilization, renewable energy and carbon management, water stewardship, and social fairness”. (Braungart & McDonough, 2012) All five pillars are always subject to continual improvement. (Braungart & McDonough, 2012)

The material category is split to two, the material health category which examines the ingredients of the materials used and ensures that harmful materials are kept to a minimum and the material reutilization category which addresses product design where materials can safely be reclaimed and entered either into the natural biological cycle or into a technical cycle, ie. in industry. (C2C product, 2014)

The renewable energy part envisions industrial energy, energy used in industrial processes as clean renewable energy and offset resulting carbon emissions. (C2C product, 2014)

The fourth category is water stewardship, which deals with clean water as a precious commodity, and carries out an assessment on industrial impacts on water resources by

identifying and optimizing on any resulting chemicals. (C2C product, 2014)

Cradle to cradle started as a theory, but quickly developed to practice over the past decade. It created a completely new vision of material and their flows in industries. The concept brought about the idea of imitating the natural world, in which an organism's waste enters the ecosystem as food for other living things. By the same token, materials in cradle-to-cradle enter a closed loop cycle, where wastes provide nutrients or raw materials for nature or industry.

Two main material flow patterns are identified within the cradle to cradle model, namely biological and technical cycles. (Braungart & McDonough, 2012). The first cycle is nature's nutrient cycle, which is fed on biological metabolisms. For materials to enter and efficiently circulate within this cycle, it is necessary that they be biological nutrients, such as biodegradable materials, that are designed to be safely disposed-of in nature to be used for the nourishment of living systems, depicted in Figure 2-1. The second types are the technical metabolisms, designed to mimic the natural cradle-to-cradle cycles in industry in forming closed loops in which synthetic materials and natural resources act as technical nutrients that are reintroduced in the technical cycle in an eternal production, recovery and manufacture cycle. Technical metabolisms are shown in Figure 2-2. ("The cradle-to-cradle alternative," 2003)

In an ideal situation, all man made systems use the ultimate source of renewable energy, that from the sun.

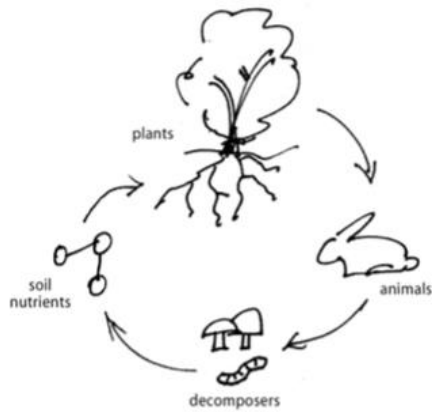


Figure 2-1: Biological Nutrient Cycle

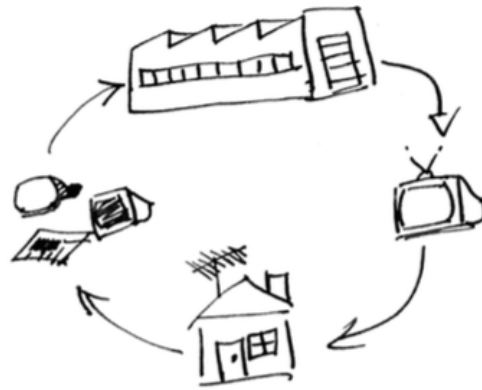


Figure 2-2: Technical Nutrients Cycle

Source: (Braungart & McDonough, 2012)

2.3.3. Life cycle analysis

According to the definition provided in ISO 14040, a life cycle assessment (LCA) is the "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (ISO 14040: 2006). In common terms, LCA is an environmental tool that tracks a product from its cradle, i.e. raw materials acquisition from natural resources through the production, transportation, use, until it reaches its grave, i.e. its final disposal. (Baumann et al., 2004). By including environmental assessment, risk analysis, and auditing, it is useful in exploring and quantifying the human-environment intervention. It is useful in providing quality information in order to serve purposes of analyzing environmental impacts as well as to provide a framework for decision-making. (Bidstrup, 2015).

Life cycle assessment can be used to provide useful information on products environmental impacts or as a comparison tool for technologies and systems in industries. Results obtained can consequently be used by decision makers in governments,

companies or used by product developers (Getting to Green, 2012).

2.3.4. Eco-Efficiency

The Eco-efficiency theory revolves around a concept of producing more goods using less natural resources and generating less waste and pollution. The World Business Council for Sustainable Development, WBCSD (2000) defines eco- efficiency as “the delivering of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle, to a level at least in line with the Earth’s estimated carrying capacity”.

Eco efficiency offers an evaluation of a company in terms of economical and environmental sustainability in the life cycle of a product. Some of the major criteria eco efficiency evaluates according to the WBCSD are (Perdan, S., & Azapagic, A., 2010):

- Amount of material consumed;
- Amount of Energy consumed;
- Toxic emissions and/or waste;
- Degree to which the material used are recyclable;
- Degree of sustainability of renewable resources;
- Product durability;

2.3.5. Industrial Ecology

The term Industrial ecology (IE) is a term that appeared for the first time in the 1990s, despite the fact that the concept itself existed long before that. It is used to refer to different multidisciplinary concepts, among which are industrial material and energy inflows and outflows and related environmental penalties of these flows. Consequences considered include harmful effects on the environment and the use and transformation of resources. According to Frosch and Gallopoulos, the “traditional model of industrial

activities”, results in environmental and social costs, such as ozone layer deterioration, global warming and harm or death of humans. (Dumoulin& Wassenaar, 2014)

The concept of industrial ecology is much like cradle to cradle; it imagines a situation where industry imitates natural ecosystems. In other words, industrial ecology urges the concept of waste elimination and complete utilization of all materials. In such a system, all materials and energy reenter a cycle where there are used by some organism in the system. (El-Haggar, 2007)

In natural systems, living organisms survive and consume each other's waste matter. Waste produced by animals and dead plant remains are digested by microorganisms to produce nutrients that are reused by living plants. Although some waste materials may be generated from these cycles, the system manages to consume what it produces. (El-Haggar, 2007).

Applying the latter concepts of nature, industrial ecology encourages complete utilization of resources in production and consumption.

Industrial ecology includes different multidisciplinary approaches linked to concepts in environmental science, engineering, business, and policy. While concepts of industrial ecology seem logic and self explanatory, it goes deeper than “an evaluation at a glance” as it incorporates a systems perspective.

A factory with air emissions can be useful to demonstrate the significance of considering the system as a whole. If air pollution in the factory is merely addressed by scrubbers that capture particles, then the only thing going on is replacing one type of pollution by another type, i.e from air emissions to sludge. The improper disposal of such material

may expose water bodies to pollution. The idea of industrial ecology boils down to an integrated solution of environment and economy.

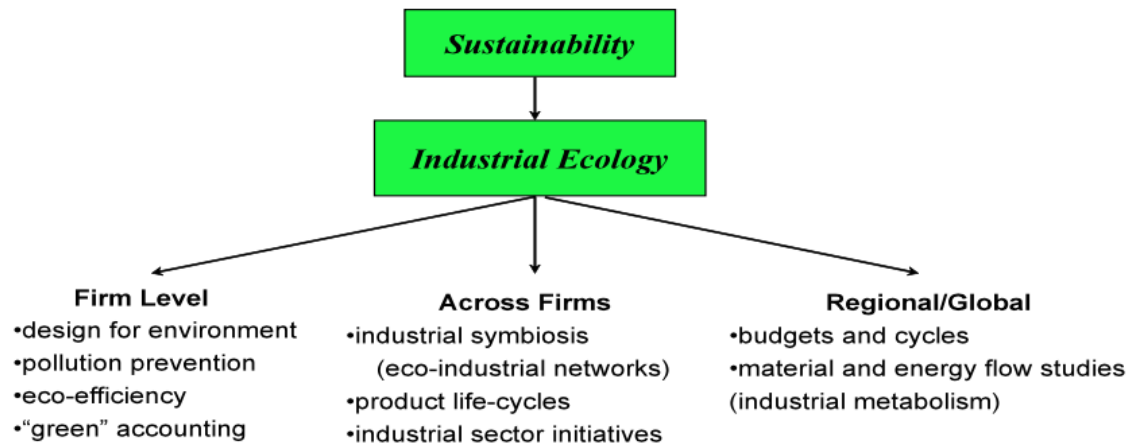


Figure 2-3: Three Levels of Industrial Ecology

Source: Clini et al (2015)

Industrial ecology operates at three different scales, at a facility level, Across Firms or at Regional levels as shown in figure 2-3 above. (Clini et. al, 2015)

Industrial ecology at a factory/facility level addresses things like pollution prevention, eco- efficiency and energy efficiency. These methods have long been tested and proved useful in combining both economic and environmental concerns. This happens when environmental performance is made measurable in terms of cost.

Within the factory level, industrial ecology takes into consideration design for environment which takes into consideration the impacts of activities beyond the gate of the factory, ie, the inputs and outputs of the factory (Clini et. al, 2015). This in a way can be considered a life cycle approach.

Across Firms/Organizations level includes resource and information exchange between

firms and organizations practicing similar activities or across different sectors. It takes into consideration supply chains, life cycles, design and manufacture, distribution and disposal. This is parallel to Life cycle, industrial symbiosis and eco industrial parks (Clini et. al, 2015).

The bigger and most complex picture of all levels of industrial ecology is a regional and/or global one. Industrial ecology on a global level Traces material and energy flows across regions, economies to obtain the final resultant of exchange processes through production and consumption from extraction to final disposal (Clini et. al, 2008).

Five major tools can assist in successful implementation of industrial ecology, these being (Clini et. al, 2008):

- Design for environment (DFO)
- life cycle analysis and assessment (LCA) (previously defined in section 2.2.5)
- material flow analysis (MFA)
- policy implementing industrial ecology
- industrial symbiosis

The first four are important when implementing industrial ecology at any of the three levels defined, while the last is mainly concerned with eco industrial parks.

Design for environment (DFE) is an approach that takes environmental impacts of a product, process or facility into consideration in the early design stages to ensure an optimized environmental, economic and social design. The design also requires that other important design attributes, namely the practicality and easiness of assembly, reliability, safety, or serviceability are taken into account.

Material flow analysis (MFA) are used to track and enumerate material inflow and outflow, mainly energy, water and materials through a network of processes. It is an effective tool to use in all cases, whether in one factory, in the case of industrial complexes, regionally or along a supply chain. (Clini et. al, 2008).

Industrial symbiosis (IS), sometimes also called eco industrial park, is a term used to describe exchange of materials, energy, water between different facilities where the waste of one is the feedstock of another. (Clini et. al, 2008). Industrial symbiosis is a win-win situation where industries attempt to find uses for their by-products and waste. The first and one of the most well known success cases of Industrial symbiosis is that of Kalundborg, Denmark, which included resource cycling between industrial facilities (Lombardi et.al, 2012). The Kalundborg Industrial symbiosis is depicted in Figure 2-4 below.

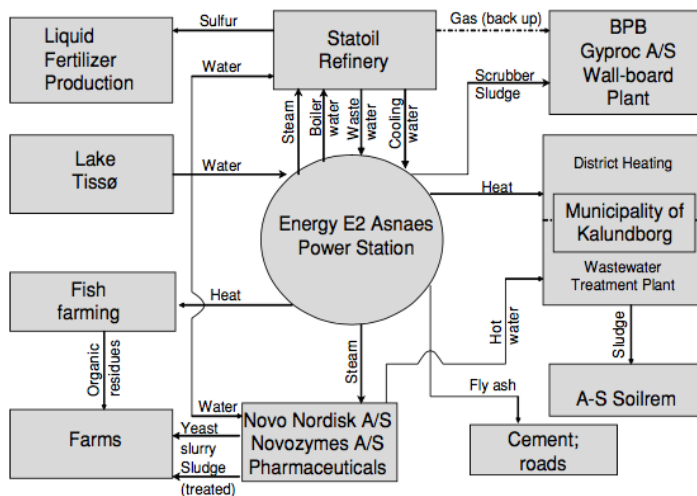


Figure 2-4: Industrial Symbiosis of Kalundborg, Denmark

Source: Chertow, 2007

Some of the policy concepts entrenched in industrial ecology are as follows:

1. Greening the Supply Chain, a requirement also specified in the cradle to cradle product certificate and requires of buyers to take on responsibility of checking the source of their purchases and to indicate specific levels of environmental responsibility of their suppliers and vendors. Under this policy, companies are able to meet their compliance requirements using their own internal environmental standards by choosing suppliers who meet their "green" goals . (Clini et. al, 2008).
2. Extended Producer Responsibility (EPR) is another policy that has gained significant attention in the recent years and relies on the fact that manufacturers assume responsibility for their products during its entire lifetime. Parallel with industrial ecology, EPR includes an embedded life-cycle approach by handling and assuming responsibility for the product's environmental impacts even beyond the factory. (Clini et. al, 2008).
3. Environmental Certification is the process of evaluating and awarding certain products or classes of products and acknowledging excellence in environmental protection against some predetermined criteria. Certification carries out the evaluation in a lifecycle perspective including the value chain to determine if sustainable practices were used throughout. (Clini et. al, 2008).

2.4. Sustainability systems and standards

Many standards came to existence to normalize and regulate practices that enhance the protection of the environment, human health, safety and working conditions. Standards

therefore provide guidelines required to avoid existing, possible or probable factors that contribute negatively to the health of the general public and environment.

Since sustainability is at many instances mixed with eco friendliness and ecosystem health, most of the sustainability standards relate to the environment. International standards have been developed for this purpose and are used worldwide.

2.4.1. ISO 14001

The International Organization for Standardization (ISO) have constantly been the leading body in the launching management standards in different disciplines. In response to increasing environmental awareness and concerns, ISO expanded the scope of standards addressing environmental issues in organizations and industries resulting in the growing ISO 14000 family which currently “includes environmental management systems, environmental performance indicators, life cycle assessments, eco-labels, and product design” (Nawrocka, D. et. al, 2009). The Environmental Management Systems sets of documents were mainly formulated to guarantee the safety and suitability of materials and processes involved in the provision of services be it of industrial or business nature, with regards to the environment and impact on the public health (ISO, 2015).

According to ISO's, the purpose of Environmental management systems is “to provide organizations with a systematic framework to protect the environment and respond to changing environmental conditions in balance with socio-economic needs”. (ISO 14001: 2015).

First introduced in 1996, and the updated in 2004, ISO 14001 Environmental management system (EMS) is one of the most widely accepted and adopted standards.

The standard attempts its goal, i.e. improved environmental performance through concepts like the prevention and mitigation of environmental impacts, mitigating the potential adverse effects of the environment on the organization, focus on product and service through its life cycle and compliance with applicable laws. (Ciravegna Martins da Fonseca & Luis Miguel, 2015; ISO 14001: 2015).

Since alarms about health and the environment are escalating as never before, standards like ISO 14001 played a vital role in pushing industries and businesses towards locating and address negative impacts resulting from their practices, and setting appropriate policies to tackle the specific situation (S.Morris, 2004). These include:

- As a response to the global development and competition, industries benefit from being part of an internationally accredited system rather than a local one. Many companies even initiated supplier evaluation schemes that include environmental and social criteria. (Seuring, S., & Müller, M., 2008)
- Policies to reduce/conservate resources by reducing the amount of virgin raw materials use, thus reducing waste and saving the environment, improving company's reputation, thus increasing the company's competitive advantage.
- Helps companies comply with local regulation and standards. (Registrar, 2015).

2.4.2. Health, Safety and Environment and OHSAS 18001

For long, health and safety were associated to occupational health and safety regulations

and as such, were strictly limited to matters appearing in the workplace. Such programmes were designed to ensure worker protection from hazards resulting from existing conditions in the workplace and in the mean time, to enhance a healthier working environment and productive workforce. It was restricted to those issues which arose within the workplace.

Risk, according to OHSAS 18001 is the “combination of the likelihood of an occurrence of a hazardous event or exposure(s) and the severity of injury or ill health that can be caused by the event or exposure(s)”. (BS OHSAS 18001:2007)

Pronounced industrial accidents, shed the light on and raised awareness about serious risks posed in organizations and the possible undesirable impacts of technology.

(Fernández-Muñiz et al., 2012)

Not only do industrial accidents cause harm to human beings but are also capable of provoking massive financial losses at times as a result of possible damage to production machinery, technology, and firm’s reputation. This, in return contributes negatively on the company’s competitive edge and economic status. (Fernández-Muñiz et al., 2012)

Some classified occupational risk according to severity, i.e. killer risks, other perils or cross-functional risks. Killer risks are events that may cause termination of operations, other perils are those events causing disturbed operations and cross-functional risks are risks that may lead to possible financial loss of reputation. Since occupational risks pose major threat to both business and workers, they need to be continuously addressed, treated, monitored and reported. Strategies need to be developed for their prevention or at

least for reducing their impacts through control systems (Olson and Wu, 2010). This implies the developing of hazard management plans and updated emergency tactics. (Khan and Abbasi, 1999). There are several benefits to applying an OSHAS 18001 management system, some of these being listed by (Fernández-Muñoz, B. et. al, 2012) as achieving the following:

- To promote firm's reputation
- To comply with legislation
- To improve employee's working conditions
- To improve relations with public authorities
- Pressure to follow competitors
- To satisfy customer demands
- To satisfy supplier demands
- To improve firm's competitive advantage
- To maintain socially responsible behaviour
- To reduce operational costs
- To prevent accidents & incidents
- To maintain sector leadership in safety
- To integrate safety into corporate strategy
- To avoid labour union pressure
- To improve employee motivation
- To avoid legal sanctions

Although such regulations implied constructive steps towards healthy work environments, global environmental issues outside factory gates seemed to be perturbing

to an extensive number of people from all levels of the society. A rising number of regulations addressing harmful environmental impacts resulting from operational procedures obligated manufacturers issues to be incorporate health and safety in operational practice. In compliance to regulations and to address the latter, many businesses included the external environment in their health and safety policies.

The increasingly mounting apprehension over environmental issues along with the stringent regulations requirements has stimulated serious attention to EHS responsibilities in the business world.

To effectively manage EHS, and to emphasize commitments and targets to external stakeholders and to the public, many businesses issue annual EHS reports. Environmental issues may be included in the same EHS reports or may be a stand-alone report.

2.4.3. C2C Product Standard

The product standard aims at providing guidelines such that products and processes are designed and developed in a way that supports diversity. This applies to all systems, natural and technical, products and processes.

The concept of Cradle to Cradle design was developed to imitate the healthy, regenerative productivity of nature, and the system consequently looks at all materials as resources rather than waste and liability.

Most businesses globally still seek being more efficient, i.e. lessening the harmful environmental impacts by optimizing current systems, even though they may be wrongly designed in the first place. cradle to cradle, however, undertake an attitude of deciding on

outcomes and choosing a right design in the first place to meet them. Using the terminology used in the standard, cradle to cradle works on being more good rather than less bad.

The product standard takes designers through a process of continual improvement and the evaluation is carried out by examining five quality categories, these being: material health, material reutilization, renewable energy and carbon management, water stewardship, and social fairness. There are five possible certification levels provided in each category, Basic, Bronze, Silver, Gold, or Platinum. The lowest achieved level represents the product's overall rating. (MBDC, 2012)

2.5. Sustainability frameworks developed

In an attempt to move closer to sustainable development, continuous efforts and propositions were made, and numerous frameworks appeared in the industry (paradigms in the design) in different regions, times and by different people, all grounded on a set of values, procedures and tools, some of which are Natural Capitalism, the Natural Step, Cradle-to-Cradle (C2C), and Permaculture. (Peralta et. al, 2015)

2.5.1. The Natural Step

The two major trends occurring, i.e. the degrading natural systems along with the increasing population and rising consumption are compared to the likelihood of two sides of a funnel converging upon each other (James, 2004). According to the founders of the framework, no one can tell the exact time when irreversible consequences will occur (James, 2004).

The natural step framework introduces four system conditions that need to be satisfied to

comply with the criteria of a sustainable society. These are the following (James, 2004):

1. That “nature is not subject to systematically increasing concentrations of substances extracted from the Earth’s crust”. Since much of the industrial needs of human require mining activities that extract and use materials from below the Earth’s surface. Substances as such include “heavy metals, such as cadmium, lead, mercury, minerals such as phosphorus, and fossil fuels”. Industrial use of these substances, result in emissions such as carbon dioxide and nitrogen oxide that accumulate in nature at rates that exceed their natural occurrences. While other mined substances like metals and minerals cannot break down further (since they are elements), many like mercury, lead, and cadmium are already toxic in their natural forms. This system condition borrows its concept from the first law of thermodynamics, which postulates that energy can neither be created nor destroyed. The same applies for matter in normal chemical reactions. In real life, this implies that no matter will disappear. This is why whenever these heavy metals and minerals are out, they are likely to remain.

2. The second system condition indicates that substances mined by humans from below the earth’s surface should be brought down to minimum. Substances mined include but are not limited to heavy metals, minerals, and fossil fuels. The mined substances along with the emissions such as carbon dioxide and nitrogen oxide released during their burning or processing are constantly accumulating in nature in concentrations that far exceeds their natural levels. Since many of these metals and minerals are elements, they remain in their same form in nature and because many of them are toxic, their concentrations might pose risk to humans and to the

environment.

3. The third system condition indicates that for a society to be sustainable, there should be no or minimum physical degradation. This condition refers to human activities that cause a break down in natural systems faster than their recovery capacity.

4. The fourth system condition indicates the social dimension of sustainability. This condition postulates that if basic human needs are not met, there will be no way the previous three conditions can be met. In other words, people will continue their unsustainable practices as long as they have no other way to meet their needs. The unequal wealth distribution also creates an unstable situation that leads to conflict.

2.6. The sustainable development journey

Owing to urging public environmental distresses, and the stringent policies being developed, the past couple of decades have witnessed changes in the way business is being pursued. (BSDglobal, 2009)

Reformers who have previously been concerned about reducing non sustainable activities to acceptable levels, are no longer discussing compliance, but are alternatively directing their efforts to a state which they call “beyond compliance” Many have attempted to describe the journey to “beyond sustainability” (McDonough & Braungart, 2013)

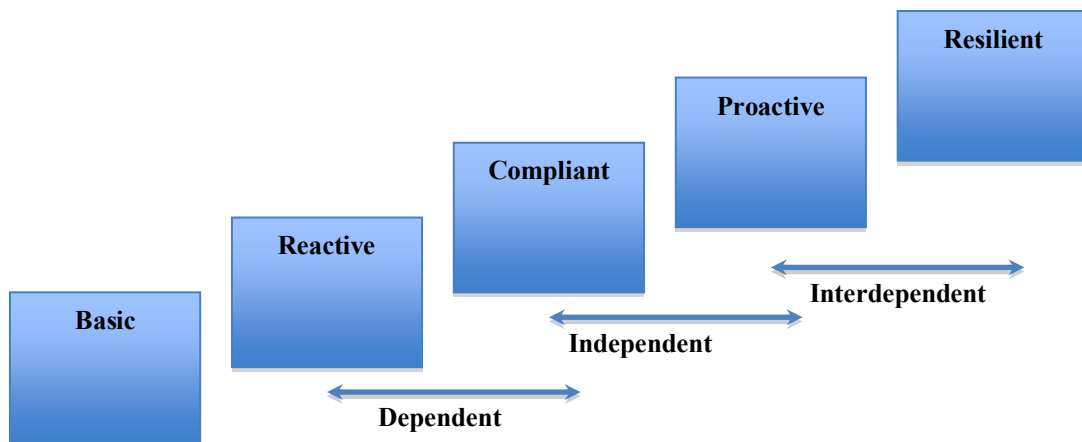


Figure 2-5: stages of Sustainable Development

(Source: Governance, n.d.)

When no pressure exists, most businesses operate in an “as usual mode” paying little or no attention to the impacts of their activities. They would only respond to disasters or obvious issues that may expose them to legal action or reputation loss. Under this theme the "polluter pays" for the environmental damage caused by the activities of the business. While this theme penalizes damage, it has constantly been criticized for being open ended, flexible and open for different interpretations. (Allen, 1992) The scheme of polluter pays is against sustainability since it does not specify an upper bound for which a polluter can compensate for loss by paying or fixing the damage caused. (Ambec & Ehlers, 2014). This scheme is represented by the reactive phase in Figure 2-5.

The movement towards sustainability, according to many, starts with regulations. (El-Haggag, 2007). Industry needs to pass through a three phase journey to attain sustainability, these “start at environmental compliance, through to risk management, to long-term sustainable development strategies”(BSDglobal, 2009).

The journey begins with stringent legislations and regulations, that set obligatory compliance limits. Deviation from these limits lead to penalty to the firm. The conception of environmental regulations, both local and universal creates a necessity for compliance, thus initiating improvements in environmental performance. These improvements however just manage to avoid liability and usually fall under reactive or compliance in Figure 2-5. Compliance mode also imposes unanticipated costs on the firm that often intimidates profitability. The most pronounced financial liabilities under this theme are those related to remediation, end of pipe treatment, clean-ups and penalties for violations of legislation. (BSDglobal, 2009)

Since failure to foresee environmental liabilities may lead to serious threats to organizations, businesses prepare remediation and abatement measures in the first place to comply with legislation and to prevent charges. (BSDglobal, 2009)

Compliance for environmental protection is generally considered mere obligation by businesses and is generally considered an unnecessary burden. (BSDglobal, 2009)

To reduce the costs induced by compliance requirements and legislation, i.e. cost of environmental cleanups and claims, some businesses undertake a rather proactive method in the following phase. This phase is an Environmental risk management, where businesses carry out dedicated studies to evaluate the amount of risk induced by their activities and working towards the prevention or reduction of environmental liabilities implied by potential risks and environmental hazards thus minimizing the costs of regulatory compliance. The risk management tactic provides better reaction flexibility than that available through regulatory compliance. To be able to take hold of their

environmental performance, some firms carry out environmental health and safety (EHS) assessments, develop environmental policies, and implement environmental management systems (EMSs). Practices such as pollution prevention or waste minimization and the elimination of health and safety hazards are commonly undertaken to execute policy objectives in real life. (BSDglobal, 2009)

Challenged with the mounting load posed by legislation, some establishments decide to implement comprehensive sustainable development programs to go beyond compliance. This is the final stage of the journey, when companies realize that implementation of sustainable business strategies may introduce new opportunities to their business and enhanced quality, the business and sustainable development phase in Figure 3-2 and proactive and resilient phase in Figure 2-5. This stage offers win-win situations, which can achieve combined benefits of environmental excellence, improved prosperity, and better competitive advantage. (BSDglobal, 2009)

CHAPTER 3 : ROAD MAP

CHAPTER 3

SUSTAINABLE DEVELOPMENT ROADMAP

3.1. Sustainable Development Roadmap

Since its establishment, the sustainability concept was dealt with in different ways and according to different definitions. The multi-dimensional concepts of sustainability cannot be successfully dealt with on an ad hoc or fragmentary basis. Most of the stakeholders, however, will continue to handle one aspect of sustainability in isolation.

The main purpose of a roadmap is to bring together numerous concepts, previously dealt with independently, and link them to establish the fundamental practical steps, the flow path and the direction for successful implementation of sustainability. In a road metaphor, the roadmap is a vehicle that takes the various sustainability concepts from the starting point to sustainability as a final destination, depicted in Figure 3-1 below.



Figure 3-1: Sustainability Process Diagram

An effective sustainability roadmap must take into consideration four significant areas:

1. Strategic approach (Vehicle)
2. Compliance/Beyond Compliance (Descriptive Destination)
3. Resource sustainability (Milestone in Implementation Phase)
4. Supply chain sustainability (Milestone in Implementation Phase)

3.2. Natural Resources: A limiting factor

Sustainability can be addressed in a number of ways, namely the available reserves, the total cost resulting from net operational, maintenance and capital investment costs,

environmental costs, energy savings from conservation, and long-term social welfare. Since it would be difficult to get hold of all aspects of sustainability, the discussion will be limited to resource sustainability.

In the beginning of the industrial revolution, both natural resources and skilled labor existed in abundance. The current situation, however, seems to undergo a reverse.

Management involves addressing the bottlenecks and limits. Since natural resources are the main limitations, policies and management practices should be manipulated such that a perfect balance between efficient material use and product is reached. (energy, water, wood, agricultural and marine resources and mined minerals and metals). This requires that technology and innovation efforts be directed to resource productivity rather than human productivity. Unlike previous corporate social responsibility programs, sustainability realizes the predetermined bounds of nature and the necessity to offset wastes and emissions, to use renewable resources and to preserve the ecosystem.

In a discussion on achieving environmental sustainability, El-Hagggar introduced using cleaner production techniques. Since both environmental management systems and cleaner production are on the top of the sustainable development tools, El-Hagggar proposes that the two can be implemented together with the goal of approaching sustainable development. The discussion proposes that if EMS is carried out for the existing activities using cleaner production techniques or pollution control systems, the organization would manage to meet its environmental obligations. By the same token, applying C2C techniques to the specific case of EMS, resource sustainability can be attained promoting an organization to beyond compliance. C2C approach pushes

organizations towards a philosophy that encourages the utilization of already existing resources and capabilities.

3.3. Stages of Resource Sustainability Roadmap



Figure 3-2: Stages of Resource Sustainability Roadmap

Source: (BSDglobal, 2009)

The proposed road map passes through several stages to mature to the beyond sustainability stage, the business and sustainable development phase depicted in Figure 3-2. Beyond sustainability indicates that industries attain a level that surpasses mere compliance to regulations, and realize business opportunities in the process of reducing resource dependence. The advancement from one stage to another indicates higher environmental performance and better economic performance. It should be noted however, that while beyond sustainability is considered self-developing, and a benefit to businesses, the stage that sets out the scene for it needs to be initially strictly regulated.

Most industries would have to pass through **three distinct stages**, outlined below:

The first stage, illustrated in figure 3-3, marks the reactive actions taken as a result of binding regulations received from a regulatory body. In an attempt to comply with

legislation and to avoid liabilities, businesses incorporate an environmental management system within the organization's policy and decision-making strategies to be able to distinguish their impacts (those penalized by law) and consequently put forward remediation and abatement measures. Such reactive strategies, contribute positively towards resource sustainability, but will not promote establishment of efficient cost control systems and growth strategies.

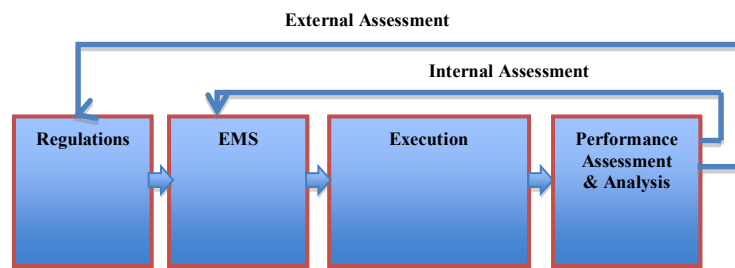


Figure 3-3: First Stage Implementation of Resource Sustainability

The second stage is a more advanced version of stage one. Organizations in this category operate under the urge to minimize risk to adhere to regulations, rather than deal with the situation by curing. This drives the organization towards adopting preventive approach. Such an approach comprises envisaging and predicting potential risks and acting accordingly to prevent environmental hazards. The preventive approach is often seen as better behavior as it provides more flexibility and an early planned response than abatement and remediation. The second stage therefore starts with a risk assessment, followed by an EMS, execution and finally a performance assessment and analysis. This process is continually subject to an internal assessment and quality control as shown in Figure 3-4.

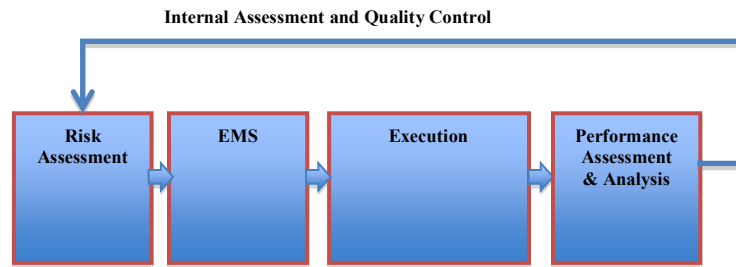


Figure 3-4: Second Stage Implementation of Resource Sustainability

The Cradle to cradle/ Industrial Ecology (I.E.) approach, proposed in the roadmap is the third stage organizations accomplish, surpasses both preventive and remediation as it seeks win-win conditions, which can realize environmental superiority, upsurge prosperity, and improve competitive advantage. The stages of the third level implementation of resource sustainability are shown in figure 3-5. The process starts with determining the baseline scenario, implementing an Sustainability Management System (SMS discussed in the following chapter), executing and carrying out a performance assessment and analysis. The process is always subject to internal assessment and quality control.

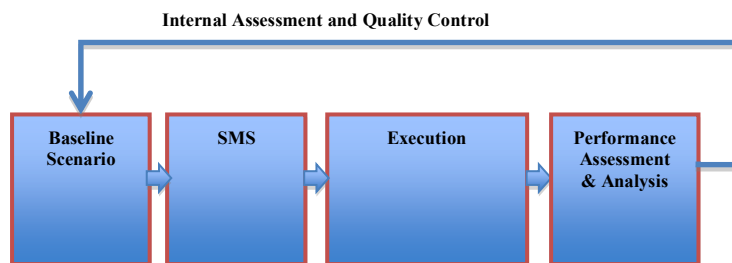


Figure 3-5: Third Stage Implementation of Resource Sustainability

In implementing cradle-to-cradle, companies integrate sustainable development into their

business strategies and earlier in the design phase. Rather than being preventive, cradle to cradle seeks opportunities.

Sustainable development strategies disclose business opportunities in areas that may have been deemed as cost inducing or mere risks that need to be handled in as usual business conditions.

3.4. Resource Sustainability Roadmap Elements

Figure 3-6 shows the sequence proposed to achieve effective resource sustainability. The roadmap begins with the determination of a baseline scenario to assess the current situation in relation to:

1. The restrictions placed in the regulatory phase
2. The internal and external issues
3. The needs and expectations of different parties.

Specific goals set within the community in the strategic resource planning phase ensure the presence of criteria for monitoring the progress of the process. The strategic resource planning process is comprised of four stages, these being:

1. Setting a resource sustainability strategy
2. Setting SMART goals and strategic objectives

A Sustainability Management System, SMS is then incorporated within the organization's policy and decision-making strategies to:

- Classify the wastes and locate opportunities of utilization or reuse in order to comply with environmental regulations.

- Incorporate C2C innovative design that allows compliance with EPR obligations.

The material collected through the SMS Analysis will be used to decide on whether the goals have been met or not. Cradle to cradle / Industrial ecology principles are applied and measured against the main goals. What makes SMS different, is that it does not target compliance with regulations alone but rather aims to go Beyond Compliance, thus contributing to the conservation of natural resources, which will finally lead to SD.

To ensure proper implementation, strategies developed should be circulated to act as guides for performance and progress measures. It should also include appointments of certain individuals to be in charge of certain sub-assignments towards the realization of the major goals within the strategy.

In order for a strategic plan to achieve its potential, it must be translated into determined execution in the **implementation phase**.

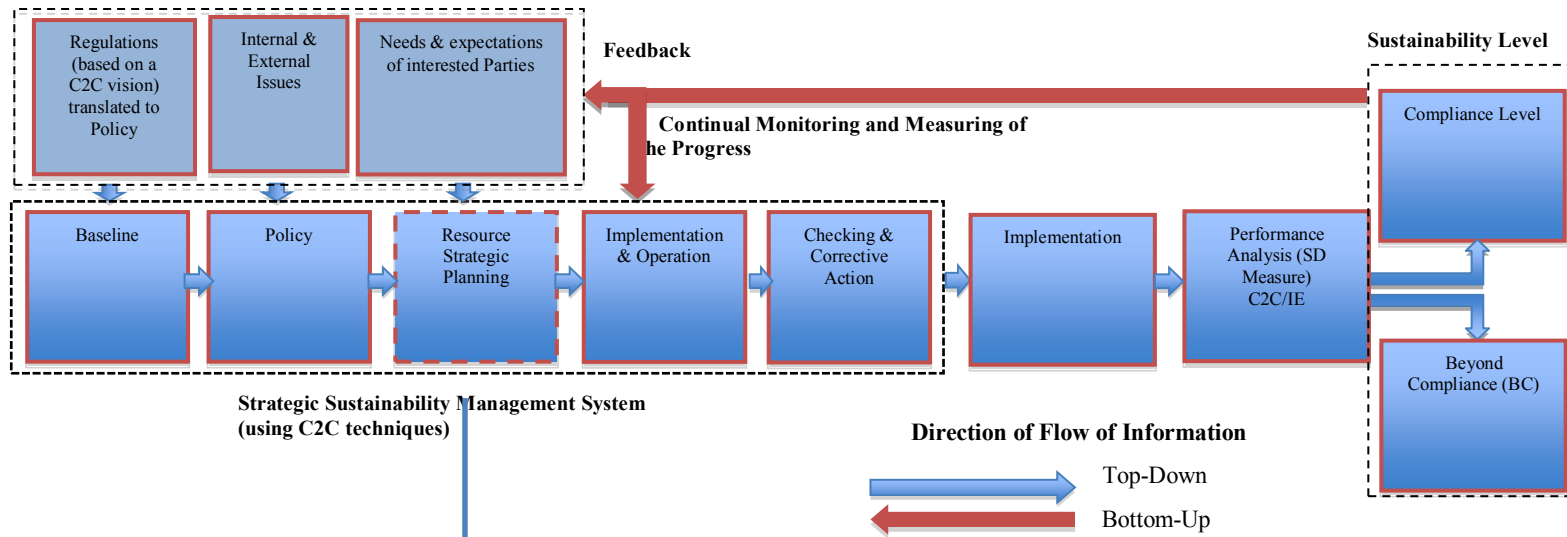


Figure 3-6: Proposed Resource Sustainability Roadmap

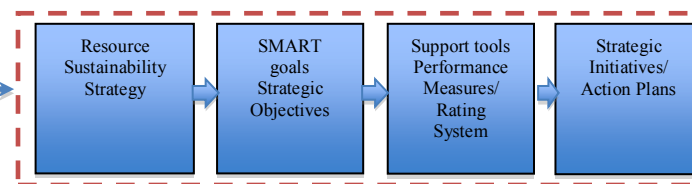


Figure 3-7: Strategic Sustainability Planning

3.4.1. Environmental Regulations

For businesses to take the initiative of incorporating sustainable development objectives and making required trade offs, a strong legislative system is essential. The effectiveness of the implementation of sustainable development plans, therefore, depends heavily on the presence of a binding regulatory body.

Given that the exact goals and targets are known, environmental regulations are set by the government to standardize policies by which organizations and projects will abide by in order to reach sustainability.

To ensure proper implementation, fines/incentive need to be utilized to credit those who take positive steps towards sustainability and penalize organizations that do not follow sustainability laws of conduct set by certain predetermined standards/rating system.

Stringent enforcement of environmental regulations would oblige investors to undertake a sustainable development culture to ensure compliance. These regulations may engage concepts of extended producer responsibility to encourage environmentally friendly design to avoid the financial burdens of remediation at the product's end of life. EPR relies on the fact that manufacturers best know their products, and are in control of the complete lifecycle, they are able to reduce the harmful impacts. Extended producer responsibility can be achieved by reuse, take back and recycling. The latter concept financially and logistically relieves the government from handling waste by delegating it to the private sector.

3.4.2. Key Issues of Concern

Along with environmental regulations, businesses should take into account the needs and expectations of involved parties and other internal and external issues. These inputs form the basis of the SMS and consequently determine issues that need to be addressed within the environmental statement. Results of this survey aims at finding out the following:

1. Involved parties
2. Major concerns of the different involved parties.
3. What are their concerns?
4. Why are they concerned?
5. What is the threshold of concern where change becomes unacceptable?

3.4.3. Sustainability management system (SMS) using a strategic approach

The first step in the roadmap is a proper implementation of a management system, also known as sustainability management systems. The information gathered from the SMS Analysis is used in the performance analysis to evaluate the actual situation against the goals set. SMS aims at achieving beyond compliance for the preservation of natural resources, finally leading to sustainable development.

Sustainability management systems can be counted as special cases of management systems that follow a strategic approach that supports resource sustainability. In the discussion related to this work, being strategic implies:

1. Having an underlying vision for resource sustainability and accordingly, be based on solid evidence, set priorities, goals and direction and set out the main tactics for achieving them.

2. Setting strategic resource management goals, related to the five major categories of C2C and identifying means of achieving them.

The systematic framework these goals are put in, offers a set of practical processes and tools for effective accomplishment of these objectives. This is particularly important during the planning phase, where a strategy needs to be put in place to ensure that the specific sustainability goals are achieved and during the performance checks.

Adopting strategic approaches to sustainable development suggests the accepting of a different set of ideas that encourage:

- Adoption of adaptive planning processes instead of rigid plans that includes a continuous monitoring, learning and improvement based on previous practical experience.
- Adaptive structure of governance
- Embracing a civic engagement process instead of a centralized one
- Move to result based management process
- Move from sectorial towards integrated planning.

3.4.4. Beyond Compliance “BC”

Beyond compliance is a term used to describe efficiency rather than mere compliance. To achieve beyond sustainability, organizations need to switch from the reactive attitude to proactive. Proactive actions usually require innovation to avoid harm in the first place while reactive seeks a kind of adjustment to ensure compliance. Motives of reactive attitudes are merely compliance while being proactive primarily seeks sustainability. While compliance cannot be an accurate measure of how close an organization is to sustainability, all journeys towards sustainability will begin with compliance. It can,

however, be considered an initiative for the quest towards sustainability (El-Haggar, 2007)

CHAPTER 4 : SUSTAINABILITY MANAGEMENT SYSTEMS

CHAPTER 4

SUSTAINABILITY MANAGEMENT SYSTEMS

4.1. Introduction to Management Systems

Despite the worldwide popularity acquired by management systems, many organizations yet follow a traditional approach to business, where procedures are “kept in the heads of the staff” rather than following official systematic procedures (The International Organization, 2016).

The establishment of management systems (MS) is however, considered of vital importance to any community if consistent goals are to be achieved over time (The Chartered Quality, 2016). Management systems usually tackle certain organizational goals, like quality or environment and are applied to various processes within an organization.

Organizations wanting to improve on their environmental performance tend to have an organized set of procedures in a formal Environmental management system (EMS) that is generally documented to guarantee clarity on the distribution of roles (The International Organization, 2016) and to ensure the presence of benchmarks. Most of these companies also seek certification from leading international standardization organizations like ISO. The procedures included in certifications specify a systematic approach that includes “concepts, principles, guidelines and criteria for establishing, maintaining and improving the processes by which an organization defines and achieves its EMS goals” (The Chartered Quality, 2016).

These standards can be implemented in all types of organization, regardless of the size,

product or service or activity. An effective management system delivers:

6. Efficient resources consumption
7. An enhanced risk management (emission reduction, preservation of natural habitats and biodiversity), and improved customer satisfaction (Business promises).

4.2. Existing Management Systems related to Sustainability

International organizations have published numerous standards to regulate business processes.

ISO 14001, released by the International Standardization Organization, is by far the most widely used framework for an environmental management system. Since its release in 1996, ISO 14001 has witnessed remarkable progress and worldwide recognition. ISO 14001 builds on an insight that an improvement towards sustainability can be achieved through a systematic process that identifies ways to prevent pollution, achieve improved environmental performance along with complying with relevant laws.

4.3. Challenges and Limitations to Existing Management Systems

Despite its popularity, much criticism has been leveled to ISO 14001 as it not being enough of a driver to lead to its main cause, environmental protection (Neumayer & Perkins, 2004). Critics with the latter point of view believe that the main motivation for companies to apply ISO 14001 is to enhance business interests including trade, supplier's preferences, public relations pressures, etc... While enhancing business can be one well respected goal, most seekers of the certification only "Do what is necessary to obtain registration, frame the certificate and place it in the most visible, public spot in the

facility's lobby then carry on with the business as usual". (Corbett, 2001). Whilst meeting the overarching requirements for certification, many organizations often fail to conform to the standard requirements in daily operations. This leads to a belief among opposers, that certifying to ISO 14001 and actual environmental improvements are not necessarily related, thus defying the actual purpose of the standard. Possible reasons for the inability of ISO certificate holders to follow standard requirements on daily basis, is the fact that the standard does not indicate environmental performance improvement benchmark requirements, and thus does not penalize for inadequate handling that occurs in the process. (Yin, 2007)

One other setback of ISO 14001 is that it does not specify any particular environmental requirements as a result of which a certification is rewarded. It rather provides a generic framework system for incorporating possible environmental impact concerns within an organization's daily activities (Heras-Saizarbitoria, & Boiral, 2013). As a result, judgment regarding the threshold of harm is left up to the organization rather than being controlled by, and based on expert specifications.

Even critics, however, cannot deny the numerous advantages of the standard, and the fact that most facilities with management systems incorporated in their daily operations are likely to exhibit greater environmental performance. (Yin, 2007)

The sustainability management system proposed, suggests some additions and modifications to the ISO 14001 certification including some performance management elements and ways to guarantee better incorporation of the standard requirements on day-to-day basis. The new proposed system suggests that the performance measures are

strongly tied to resource sustainability and may be better described by criteria performance measures stated in the C2C certificate requirements.

4.4. Sustainability Management Systems (SMS) Structure

While all follow a similar structure, differences between EMS 14001, EMS-CP, OSHAS 18001 and SMS lie in their different level of coverage and thus targets for each stage.

Table 4-1 summarizes the differences between the overall objectives of each.

The proposed sustainability management system (SMS) has the same structure as all ISO management systems, i.e. it contains the same components. Unlike the other management systems however, the SMS does not address Environmental management, HSE or quality independently but handles sustainable resource management as a package.

An SMS is a systematic approach that provides guidelines for an organization to evaluate, manage and arguably improve sustainability by optimizing on resource use. Unlike EMS, an SMS incorporates resource management into the organization's processes, thus enables it to reduce its resource depletion impacts and optimize its resource efficiency.

An SMS ensures that resource efficiency is incorporated in the production phase and the take back is designed for at the outset to enable proper recycling of materials at the end of life.

Like EMS, an SMS includes the following components:

- Management commitment and Resource sustainability policy
- Identified actually occurring and forecasted impacts from an environmental, economic and social perspective and opportunity to eliminate risks.
- Identified applicable requirements specified by law
- Sustainability objectives and targets

- Agendas (planning) and practices to comply with these objectives and targets
- Planning to allow for resource conservation policy implementation
- Training program to provide employees with required tools to achieve his/her assigned role towards sustainability.
- Implementation of the resource conservation plans
- Auditing system to document the SMS
- Communication plan to circulate the SMS
- Continual monitoring, measuring and evaluation
- Corrective/preventive actions (Assess the SMS and overall progress, and implement improvements)
- Management Review

Sustainability management systems (SMS's) are sets of management processes and procedures that enables an organization proper handling of sustainability matters and guarantees that sustainability goals and objectives are achieved and continually improved through resource sustainability using cradle to cradle techniques.

The standards are concerned with all three dimensions of sustainability impacts, namely the environmental, social and economic in both the short and long terms.

The SMS will follow the typical Plan-Do-Check-Act system model for continuous improvement. The role of each stage is outlined below:

During the planning phase, baselines are determined, possible and actual sustainability impacts are predicted and goals and targets are established. In the 'Do' phase, action plans required to achieve the goals are realized. As the name indicates, checking records progress and takes preventive and corrective action as needed. The last phase is the

‘ACT’ where the overall progress and systems are evaluated and actions are made to introduce changes to the SMS as needed.

Figures 4-1 to 4-3 show the expected evolution in Management systems. Figure 4-1 depicts the traditional ISO 14001 Environmental management systems prototype that forms the foundational model upon which both CP-EMS and SMS are based.

El-Haggar (El-Haggar, 2007) suggests the first modification to EMS, Figure 4-2, where cleaner production techniques or pollution control systems can be incorporated. While cleaner production and pollution control are related and do overlap at times, the main difference remains timing, cost, and sustainability. Cleaner production follows a “prevent better than cure” rather than the “react and treat” approach, followed by pollution. In other words, Cleaner production is concerned about preventive techniques, namely:

- Source Reduction
- Recycling
- Product Modification

Cleaner production has had many rewarding results in operating cost reduction, an improvement in profitability, reduction of environmental impacts, most of the time requiring no significant capital costs.

Along with direct benefits, cleaner production techniques can also:

- Reduce costs of waste handling, raw materials, health, safety and environmental damage
- Promote product by enhancing its public image, thus giving an organization a competitive edge.

- Assist with environmental protection compliance

In a more universal scale, cleaner production helps with global problems including and not limited to air, water, biodiversity and global warming. Table 4-1 compares between the conventional management systems and the new proposed SMS.

Table 4-1: Comparison between Management Systems

	EMS 14001	EMS-CP	OSHAS 18001	SMS
Policy	Purely targets Environmental compliance	Targets Environmental compliance using Cleaner production techniques	Targets Health, Safety & Environment issues combined	Suggests Resource Sustainability as a way to eliminate impacts on Environment, Health & Safety, to create business opportunity and to conserve resources. And conserve the natural resources
Planning	Environmental Compliance	Environmental Compliance through CP techniques	Environmental, Health, Safety Compliance	Incorporating Sustainability in initial design, accounting for cradle to cradle to create business. (Opportunity)
Implementation	According to plan	According to plan	According to plan	According to plan
Evaluation	Environmental Indicators	Environmental Indicators	Environmental Indicators, No evaluation criteria for Health and Safety	Evaluation made according to the percent recyclability using cradle-to-cradle techniques.

4.5. Beyond Sustainability Management systems: A cradle to cradle approach

Since the world is comprised of a countless number of interlocking systems, sustainability can only be attained if things are looked at in a systems perspective.

"Sustainability is nothing new- it is simply providing some structure to a set of emerging societal expectations" (Hitchcock & Willard, 2006). Beyond sustainability goes beyond Laws, Regulations and Contracts, Employee needs, Customer expectations, Environmental Protection and Community needs, to the compliance to the limits of nature.

In an organization metaphor, the earth's environment is a parent company and human society is a subsidiary one. Any harm caused to the parent company will disrupt all affiliates (The Natural Step, n.d.)

The SMS provides a decision-making structure and action plan to bring cleaner production into the company's strategy, management, and daily operations.

While cleaner production techniques opt to eliminate environmental risks and achieve sustainability, this work tries to take it a step further. This mainly is concerned with attaining an ideal situation, i.e. going beyond sustainability.

This work tries to establish the fact that to achieve ultimate resource efficiency, it is necessary that the design principles of cradle-to-cradle are strictly applied and followed.

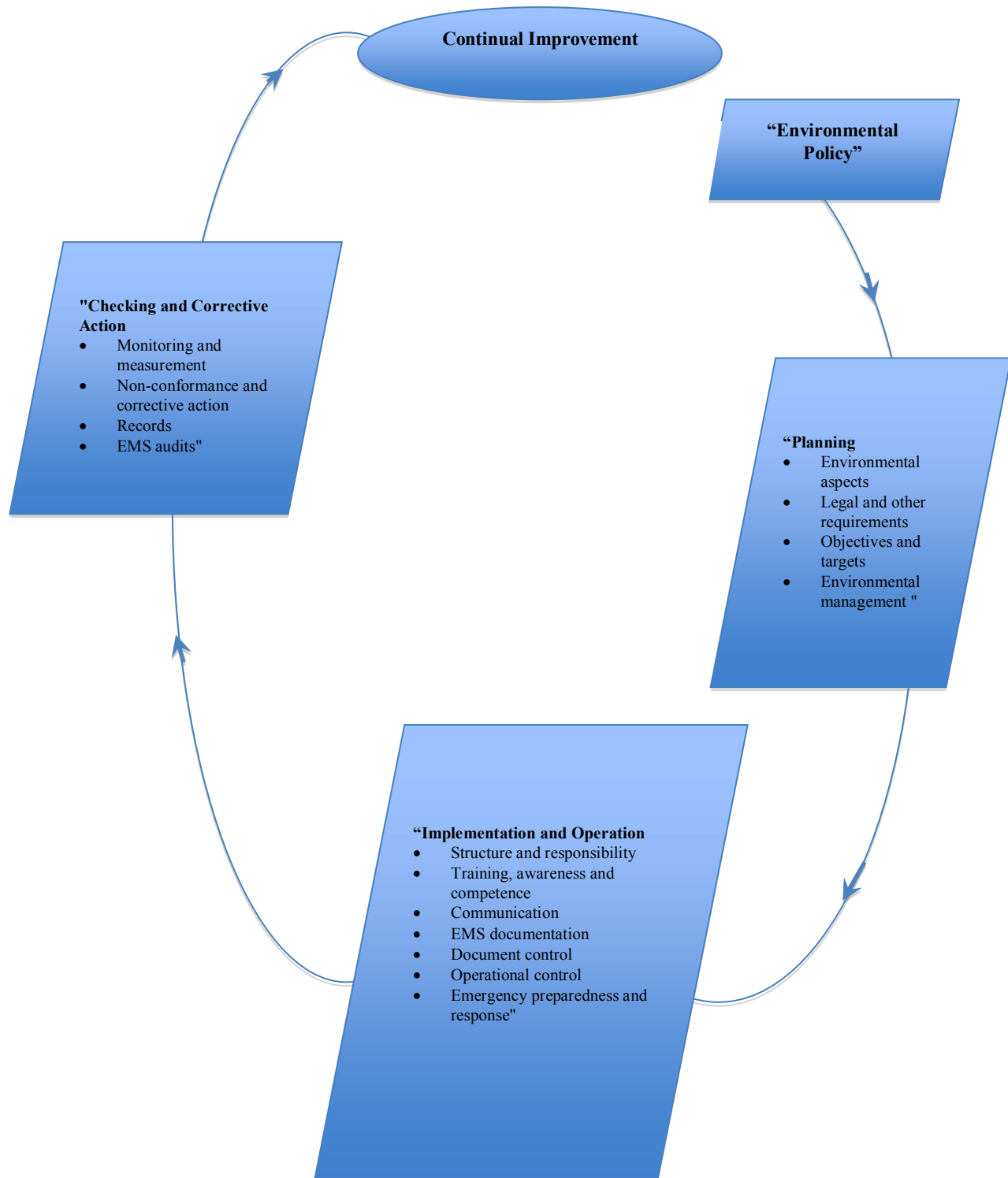


Figure 4-1: Worldwide Known ISO 14001

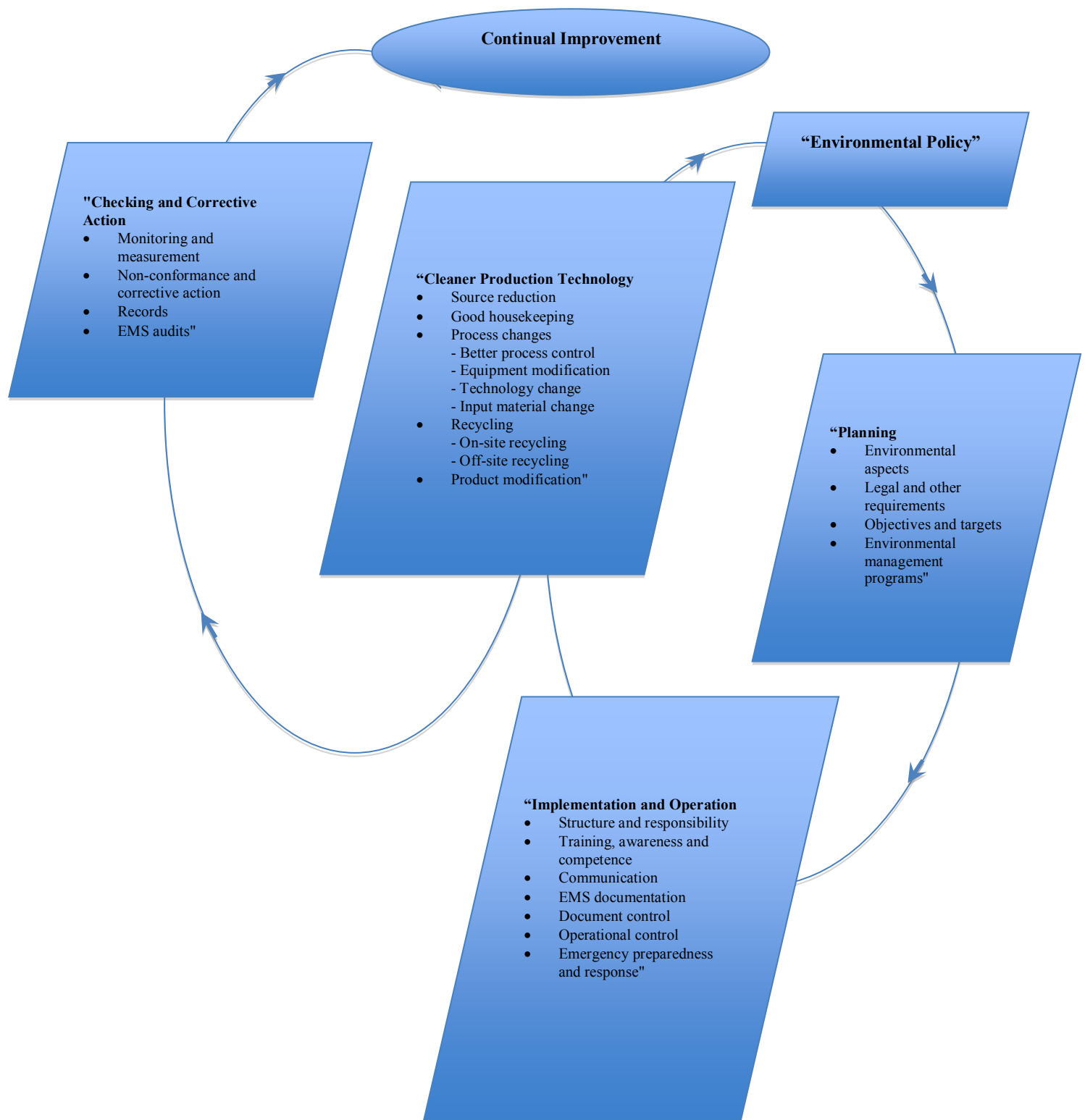


Figure 4-2: CP-EMS
 Source: (El-Haggar, 2007)

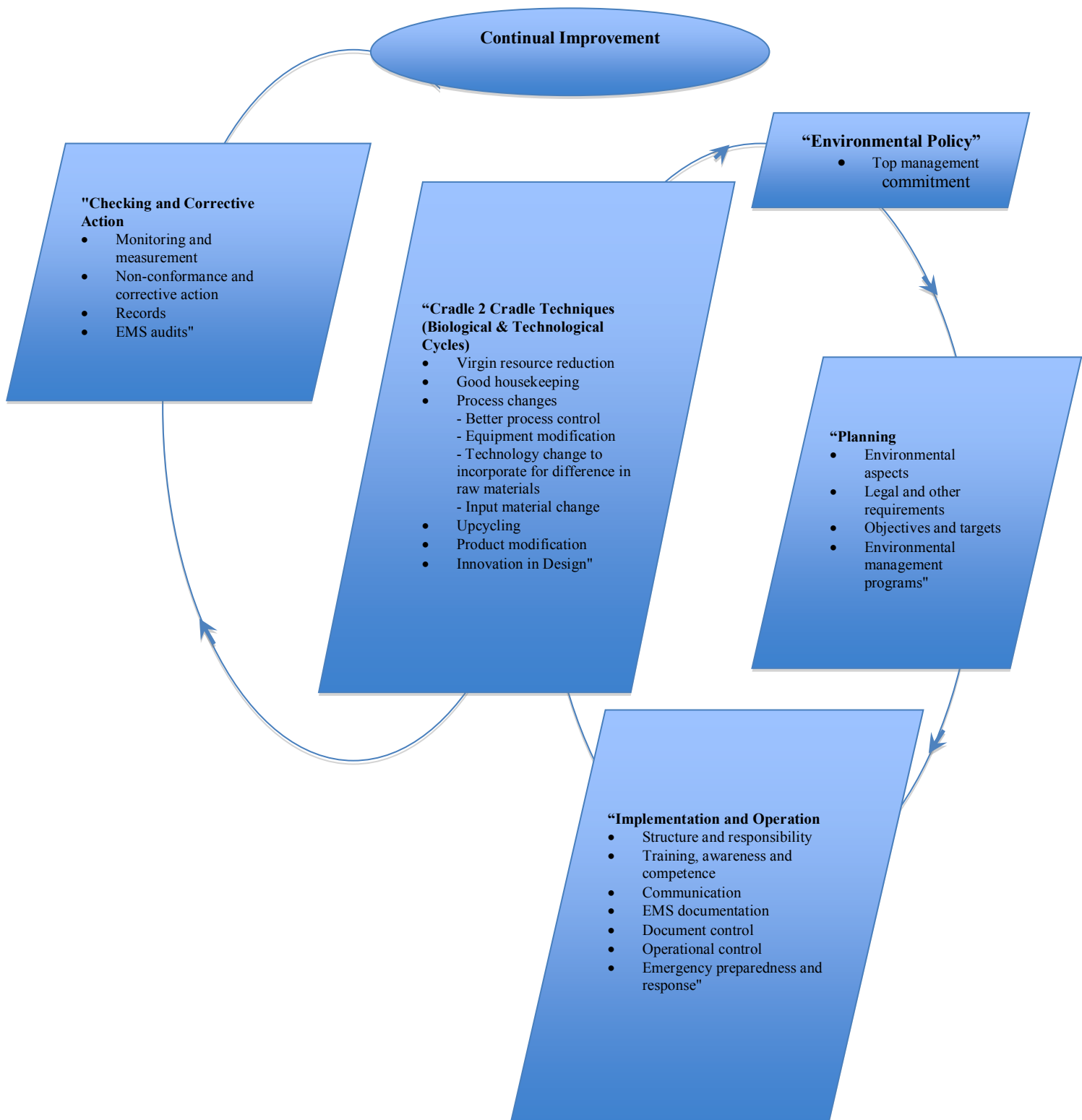


Figure 4-3: Sustainability Management System (SMS)

For the management system to properly support sustainability, certain factors need to be taken into account, namely:

1. Top management commitment to achieve sustainability
2. Specific level roles (hierarchy), on an integrated top-bottom and bottom up system.
3. With specific cradle to cradle objectives in mind, proceed with the planning process. This in other words, indicates
 - A. Determine potential factors that may possibly have major impacts on the environment. Cradle-to-Cradle standard categories should be used as reference milestones, these being “material health, material reutilization, renewable energy and carbon management, social fairness” (C2C, 2014). These significant impacts should be determined using a total life cycle analysis.
 - B. In a perfect world, these impacts should total to zero, if C2C techniques are used and efficiently implemented. At this stage it is necessary that the ‘risk’ is determined, ie. Deviation from the ideal situation and ‘opportunities’ are identified. Opportunities can either be direct, simple fixes or may require innovation in design. Since the ideal situation is the same always, deviation can be easier determined.
 - C. Compliance regulations (6.1.3 in ISO 14001-2015) that relate to C2C and that apply to the environmental aspects identified are classified. The organization should then decide on the regulations that may apply to the company.

Table 4-2 to 4-4 below summarize areas in ISO 14001-2015 that give room for C2C techniques integration.

Table 4-2: Integration of Cradle-to-Cradle Techniques

Environmental Policy	
“Top management shall establish, implement and maintain an environmental policy that, within the defined scope of its environmental management system” (ISO 14001, 2015) :	
ISO 14001-2015 as in Clause 5.2	Suggested C2C Additions
a) Is aligned with the mission of the organization and is suited for the specific activity, size and identified environmental impacts	
b) provides direction and broad guidelines for identifying environmental objectives	
c) commitment to environmental protection from certain undesirable fates (lessen the harm) NOTE: Other <u>specific commitment(s) to protect the environment can include sustainable resource use, climate change mitigation and adaptation, and protection of biodiversity and ecosystems, or other relevant environmental issues (see 4.1).</u>	Specific commitments and actions should be made to comply with the following C2C principles (Proactive strategy that goes beyond prevention) 1) Eliminate the concept of waste 2) Use Renewable Energy 3) Celebrate Diversity 4) Translate pollution into business plan e.g. Kalundborg, Denmark
d) commitment to adhere to compliance obligations;	Motivation to go beyond compliance
e) An open ended commitment to <u>continual improvement of the environmental management system</u>	From the C2C, top management should start <u>defining long-term Cradle to Cradle goals and then develop transitional strategies to achieve them.</u>

Table 4-3: Integration of C2C Techniques Using Risk Assessment Techniques

6.1 Actions to address risk associated with threats and opportunities	
ISO 14001-2015 as in Clause 6.1	Suggested C2C Additions
6.1.2 Environmental aspects Identification, specific to the organization (Listing only)	Taking C2C main impact categories into consideration, and in a life cycle context.
6.1.3 Compliance Regulations	Using C2C, identifying the significant allowable limit for each category identified. Identify threats and opportunities. Take into consideration supply chain
6.1.4 Risk related to threats and opportunities	Using compliance regulations (identified in 6.1.3) , organization determines risk related to threats and opportunities.
6.1.5 Planning for Action	This includes actions planning to tackle risks, (threats and/or opportunities) related to the identified environmental impacts and to meet specific C2C categories previously identified in 6.1.2. Organization should also include plans on ways to incorporate and apply the actions in environmental management system processes;”

Table 4-4: Integrating C2C Techniques in Setting Objectives and in the Planning Process

6.2 Environmental Objectives and Planning to achieve them	
<p>6.2.1 Environmental Objectives</p> <p>This clause indicates that an organization needs to formulate certain environmental protection activity-customized objectives,</p>	<p>These objectives will incorporate the following specific relevant company specific C2C principles <u>where applicable:</u></p>

<p>where applicable with consideration to taking into account :</p> <ul style="list-style-type: none"> a) Environmental aspects relevant to the organization's activity and its respective compliance obligations (previously identified in 6.1.1 and 6.1.2) ; b) risk related to with threats and opportunities. c) technological, financial, operational barriers/facilities 	<ul style="list-style-type: none"> 1) Material Health 2) Material Reutilization 3) Renewable Energy and Carbon Management 4) Water Stewardship 5) "Social Fairness" <p>The environmental objectives shall:</p> <ul style="list-style-type: none"> a) "be consistent with the environmental policy; b) be measurable c) be monitored; d) be updated as appropriate.
<p>6.2.2 Planning actions to accomplish the environmental Objectives</p>	<p>Plans on ways to accomplish the environmental objectives should include:</p> <ul style="list-style-type: none"> a) Action to be taken; b) Needed resources; c) Responsible persons d) Time frame for implementation e) Specific performance measures, that include indicators to quantitatively track progress achieved towards measurable environmental objectives. <p>In the SMS, this may include planning for design modification or innovation in design.</p> <p>Short term goals include design related decisions that are expected to bring an organization closer to sustainability. To decide on design goals relevant to the organization's product, service and</p>

	<p>activities, it is necessary that the constituents and materials used in the making of a product be clearly identified for environmental assessments.</p> <p>Long term goals include designing products/services/ activities that meet certain performance measures in terms of cost, material health and material reutilization potential, renewable energy, water use, cost effectiveness and honoring social systems thus approach Cradle-to-cradle in a full manner.</p>
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4.6. SMS Policy

Along with the requirements specified in ISO 14001, The SMS policy will include commitment to a modified EPR, (MEPR) in which producers will demonstrate obligation to take their products back at the end of life and process them instead of landfilling. The goals are not merely environmental risk elevation but the creation of new business opportunities)

4.7. SMS Panning

The planning section will include the determination of impacts and ways of implementing MEPR Framework, to:

- Identify all materials in the waste stream, and their forecasted lifecycle toxic or volume burdens in landfills.
- Address products end of life fate, implementing cradle to cradle to suggest possible recycling opportunities and incorporation in the new products.
- Estimate and deliver quantifiable net environmental offsets via design innovation aka. Design For Environment (DFE) provides enhanced ecological performance all through the lifecycle of a product. Some benefits include reduction in waste, energy, water, toxic materials, greenhouse gas and air emissions;

- Encourage green product design, source reduction and reuse, and appropriate collection and recycling.

4.8. Sustainability Management System (SMS)

SMS's provide organizations to which it is implemented many privileges, including:

- Provides each individual within the system an understanding of their role towards achieving a sustainable community.
- The effort is transformed from being small standalone sustainability deliverables to being an integrated, long-term approach
- Introduces a framework for the walk towards sustainability, and a set of metrics to evaluate progress across the community.
- Facilitates a continual evaluation of practices, procedures, and processes.
- Reveals occasions where costs and waste can be reduced or eliminated.
- Results in healthier indoor and outdoor environments, reducing risk
- Turns sustainability performance from being an individual attempt to being an collaborative effort.
- Classified as a sustainability pioneer, thus improving the organization's public image

CHAPTER 5 : THE CEMENT INDUSTRY

CHAPTER 5

CEMENT PROCESS

5.1. Introduction

Portland cement is comprised of calcium carbonate (generally limestone), silica, iron oxide and alumina mixed together. These raw materials are brought to a partial melting state in high temperature kilns (reaching 14500°C), fuelled by natural gas or heavy fuel oil converting them both physically and chemically into the main constituent of cement, clinker. Clinker is finally ground with gypsum, flue ash and/or sand to produce cement.

5.2. Cement Production Process

The two main ingredients used in cement production is clay, that acts as a source of SiO_2 and limestone CaCO_3 , the main source of CaO .

The mining of the raw materials, mainly limestone and clays is the first step in the process. Limestone is obtained by an excavation process from open mines by drilling and blasting operations. The excavated stone is then loaded on dumpers and taken to the plant where they are unloaded into hoppers for crushing of limestone. Clay is also loaded on dumpers but get unloaded into hoppers of a clay crusher. Other raw materials such as sand and iron ore are supplied and unloaded into open yard piles. Since a huge amount of limestone is wasted in the production process, cement industries are preferably located in close proximity to the limestone mines.

The limestone passes through several crushing stages. The first crushing stage is carried out in a jaw crusher after which the limestone is passed onto another crusher, also known as an impact crusher along with clays to bring the particle size down to a size smaller than 50mm. The resulting raw mix, usually about 70% limestone and 30 % clays is then

fed into a storage unit to store and stack the raw mix. The mix is then taken to a raw mill for grinding.

The remaining raw materials used, additives in the cement manufacturing, are high purity limestone, sand and iron ore. The high purity limestone goes through the same primary and secondary crushing and grinding stages as normal limestone to reduce its size to less than 50mm and is then stored until reclaimed for further processing.

Raw materials are fed into a preheating kiln with clay to raise the raw feed's temperature to about 800°C. The preheating process is optional for energy saving but is not essential. Other additives can also be added to the basic raw materials depending on the required cement properties and the properties and quantities of additives. The raw mix is then fed to a rotary kiln in which temperature are brought up to about 1450°C to produce “clinker”, the main component of cement.

Clinker's temperature is then brought down from 1350-1450 C to about 120 C onto a grate cooler, from where it is transported for storage. Cement is then produced by grinding clinker in a cement ball mill hopper.

The process of clinkerization generates large amounts of cement kiln dust (CKD), the main dust emission in the process along with other emissions. CKD is collected at the bottom part of the stacks through dust filter bags (baghouses).

5.3. Cement Process Emissions and Controls

The prime emissions attributed to the Portland cement industry are “particulate matter (PM and PM-10), nitrogen oxides (NO_x), sulfur dioxide (SO₂), carbon monoxide (CO), and CO₂”. Other pollutants occur in the process in minute amounts and include :

1. Volatile organic compounds (VOC), ammonia (NH_3), chlorine, and hydrogen chloride (HCl).
2. Emissions resulting from incomplete combustion
3. Fuel and raw material residues
4. Hazardous organic pollutants if the facility burns waste fuels in the kiln.
5. Trace amounts of heavy metals emitted as particulate or vapor may possibly be present in raw material feeds and fuels.

Sources of PM at cement plants include (EPA AP-42,)

1. Quarrying and crushing
2. Raw material storage
3. Grinding and blending (in the dry process only)
4. Clinker production
5. Finish grinding
6. Packaging and loading.

Most of the PM occurring within cement plants, however, is emitted in the pyroprocessing stage, which is basically the process kiln and clinker cooler exhaust stacks. Some of the dust occurring in the kiln may be collected and recycled back into the clinker process. The PH of the dust and the quality of the raw materials, however, restricts the amount that can be recycled. While some of the CKD may be returned to the process to be utilized, this may not be possible for highly alkaline raw materials. Where this is the case, only partial use of CKD is possible, rest of which is disposed or leached.

Oxides of nitrogen emissions usually occur from the fuel combustion in a process where chemically bound nitrogen in the fuel is oxidized along by thermal fixation of nitrogen in the combustion air. Thermally produced NO_x increase with the flame temperature while NO_x generally increase with the nitrogen content of the fuel.

Sulfur dioxide emissions in the cement industry occur as a result of sulfur compounds in the raw materials and the sulfur in the fuels. Since Sulfur dioxide is an acidic gas, the alkaline environment absorbs much of it, thus reducing its amount in the exhaust gases. Absorption ranges from 70 to more than 90 % in some processes.

Most of the CO_2 emitted in cement production occurs during the pyro processing stage in the main kiln. This is a calcining process, where thermal decomposition of CaCO_3 to CaO and CO_2 occurs. The total amount of CO_2 emissions occurring during the calcining stage usually range between 0.85 to 1.35 t of CO_2 per t of clinker.

Various pollutants are also emitted as a result of fuel combustion. Carbon monoxide and volatile organic pollutants are released during incomplete combustion of fuel, usually listed as total organic compounds (TOC's), VOC's or organic condensable particulate. Though in much smaller amounts than TOCs, some other hazardous organic air pollutants may also be released in the process of incomplete combustion.

Metal compounds emissions occurring in Portland cement kilns are classified by US EPA in three major groups, these being :

1. Volatile metals e.g. mercury (Hg) and thallium (Tl);
2. Semi volatile metals, including antimony (Sb), cadmium (Cd), lead (Pb), selenium (Se), zinc (Zn), potassium (K), and sodium (Na);

3. Refractory or nonvolatile metals, including barium (Ba), chromium (Cr), arsenic (As), nickel (Ni), vanadium (V), manganese (Mn), copper (Cu), and silver (Ag).

Figure 5-1 below illustrates the process of cement production and locations of different emissions.

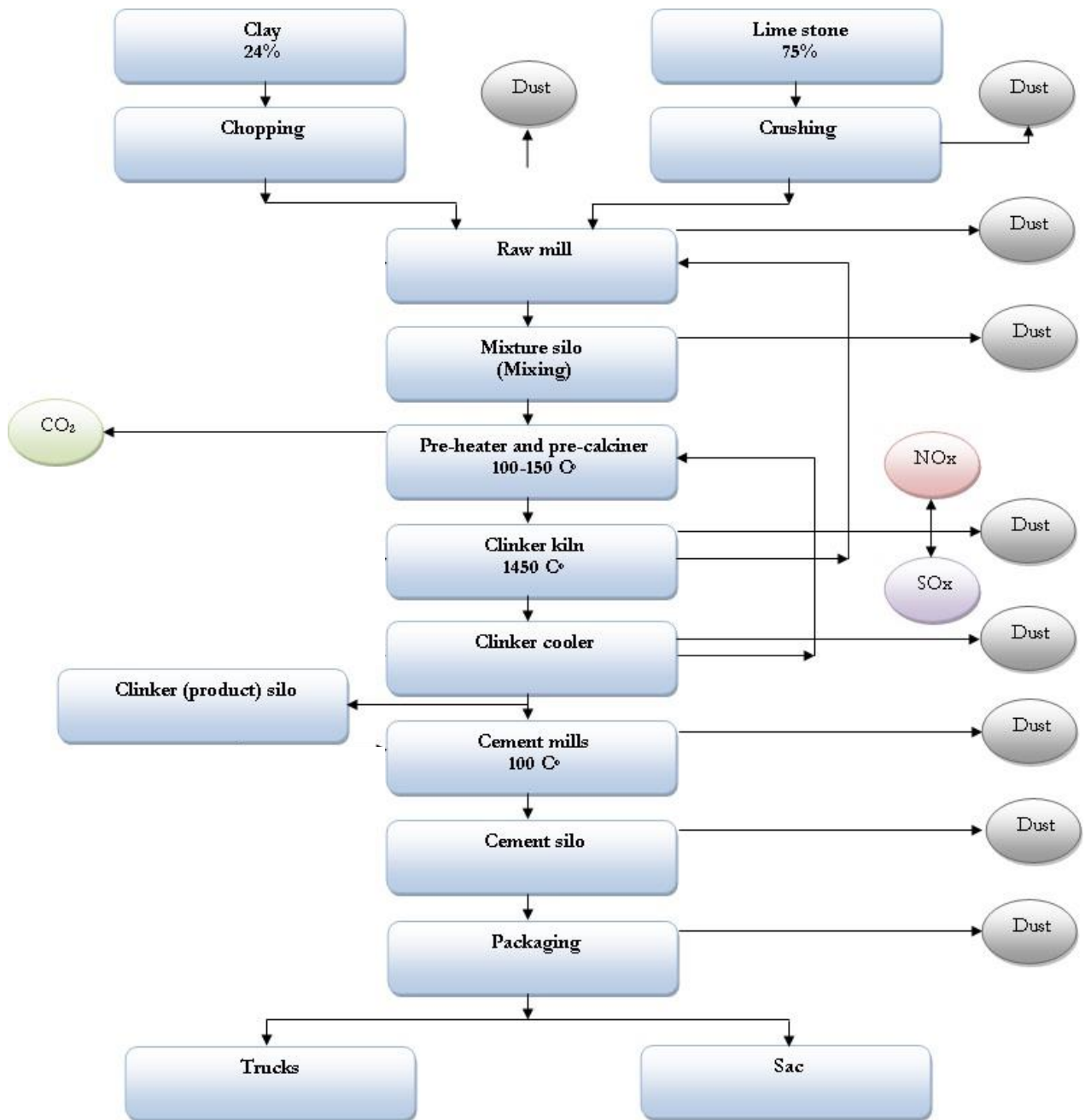


Figure 5-1: Cement Manufacturing Process and Occurring Emissions

Source: Askar et. al., 2012

CHAPTER 6 : THE CEMENT RESOURCE AND EMISSIONS MONITORING APPLICATION

CHAPTER 6

THE CEMENT RESOURCE AND EMISSIONS MONITORING APPLICATION METHODOLOGY

6.1. Model Inspiration

The model derives its inspiration from the well-known definition of sustainable society given by the natural step framework. The framework provides four system conditions for the success of sustainability, three of which formed the guiding principles of the model. The framework indicates that it is necessary to reduce systematically increasing concentrations of (The Natural Step, n.d.):

1. Substances removed from the earth's crust (such as fossil fuels and heavy metals)
2. "Concentrations of substances produced by society" (such as waste)
3. Degradation by physical means (such as mining of raw materials)

The model examines at least one option to reduce or replace each of the above activities in the cement production.

6.2. Model Objective

The model aims at achieving the following objectives:

- To understand the environmental impacts of cement production
- To locate where the impacts come from (to give room for improvement)
- To compare different alternative scenarios to each other or an alternative scenario to the baseline scenario and come up with optimum savings in emissions, raw materials and energy.

On a wider scale, the model aims on developing industrial resource and environmental sustainability, with a focus on the cement industry. It does so by applying concepts introduced previously like Cleaner Production, cradle to cradle and Industrial Ecology. The model objectives are:

1. To motivate Egyptian cement industrial leaders to make improvements “beyond compliance”;
2. To integrate strategic policies & practical tools (developed in chapters 3 and toward Cleaner Production in all cement industries in Egypt;
3. To develop a series of comparisons and sensitivity analysis implementing triple bottom line (TBL) benefits of improved resource environmental in the implementation of cleaner production concepts, tools and strategies in several major, heavily polluting cement companies in Egypt.

6.3. Model Description

The Cement Resource and Emissions Monitoring Application, model was developed to assist in estimating the environmental impacts of the cement industry and to attempt to suggest ways that could walk the industry towards cradle to cradle. To do so, the model evaluates three broad categories namely, resources extracted from the earth, emissions driven into the atmosphere, and energy efficiency.

The model is divided into Sub process models to calculate and examine impacts resulting from different activities within the cement industry.

The sub models that are analyzed in this model are divided into two parts:

1. Emissions from baseline scenario processes (Business as Usual)

- Raw Material extraction and transport to the factory premises
- Conventional Fuel transport to the factory premises
- Stationary combustion of the conventional fuels
- Waste CKD transfer to a landfill

2. Amounts of Raw Materials

The model considers all materials, including waste and fuels as resources. This part of the model calculates all amounts of raw materials to allow for comparison between possible savings from different scenarios.

- Limestone
- Clay
- Additives
- Fuels
- CKD
- Others

3. Energy Conservation

The model assumes that energy conservation can be achieved through either

- Using energy efficient kilns (thus achieving savings on the total energy requirement per tonne of clinker)
- Heat Recovery, the amount recovered is reduced from the total energy requirement from fuels, thus saving on amount of fuel

combusted (achieving resource conservation) hence a reduction in stationary combustion emissions.

The different parts of the model are described in the model scheme Figure 6-1 below. To simplify the model, some indirect emission sources were left out. The boundaries of the model is depicted in Figure 6-2.

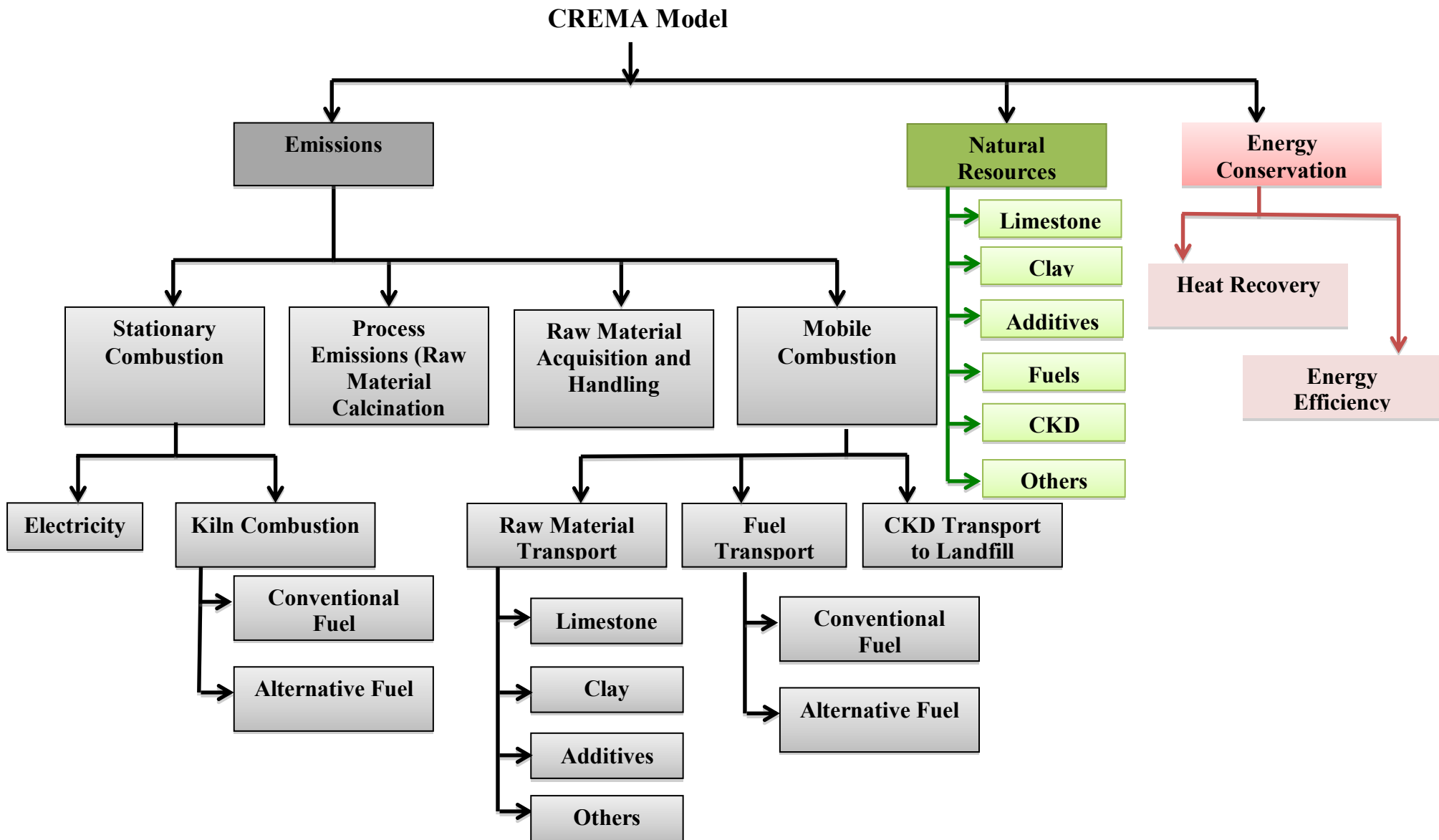


Figure 6-1: CREMA Model Scheme

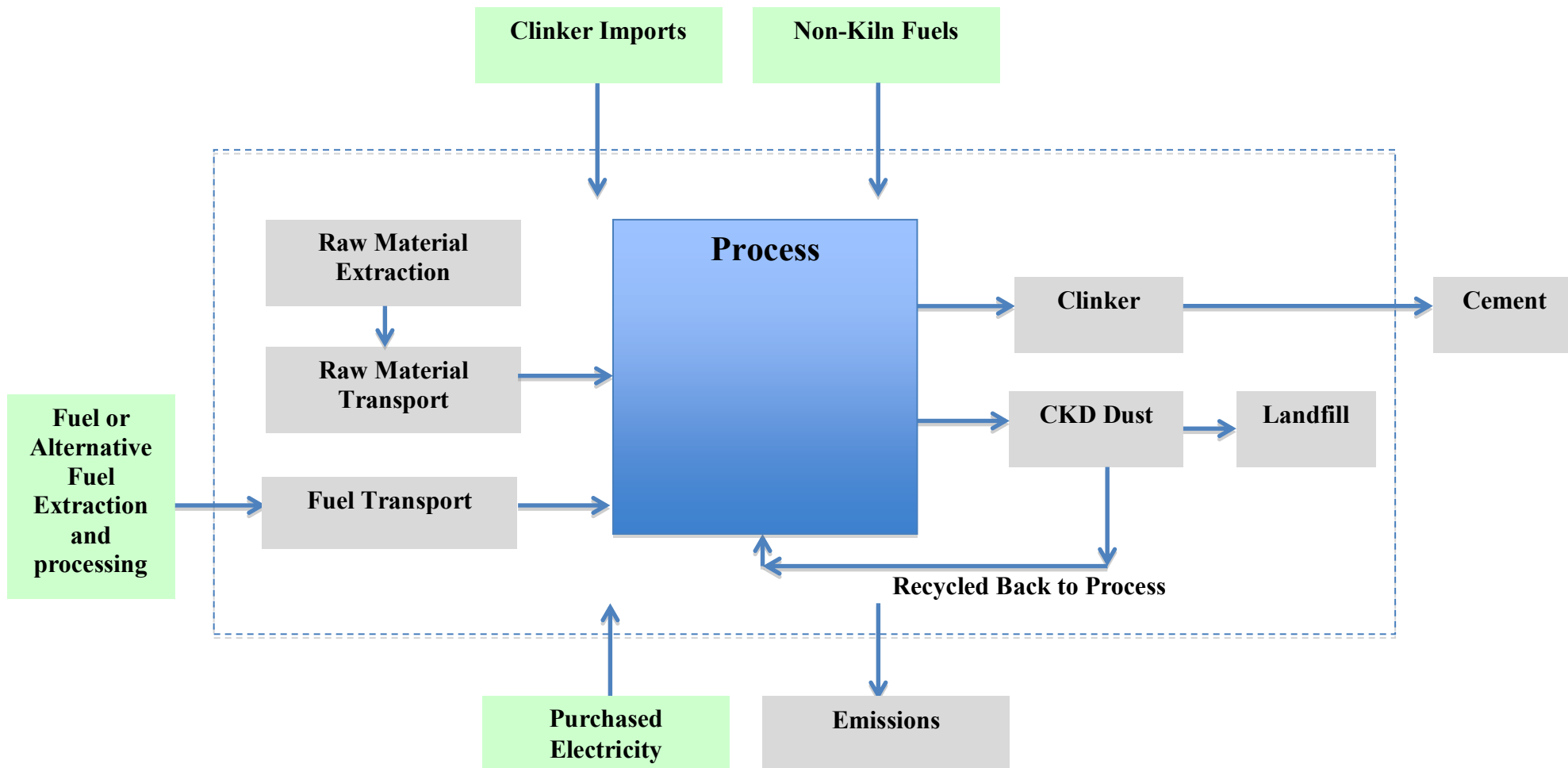


Figure 6-2: CREMA Model Boundary Conditions

The Portland cement manufacturing industry have increasingly managed to replace raw materials by waste from its own operations or from other industries to a degree that does not interfere with any of the quality or operations. Materials used include fly ash, mill scale, and metal smelting slags. (USEPA, 1995) . Waste fuels have also increasingly been used in cement kilns to replace virgin fossil fuels.

The model allows for the calculation of several alternative scenarios to test for the contribution of a certain process aspect to raw materials, emissions and/or energy savings. Some of these alternative scenarios include the following:

1. Reduction in Clinker to Cement ratio

Since most of the emissions and energy in the cement industry come from the clinker production process, reducing the amount of clinker production is expected to lead to :

- Decreased virgin limestone material use (Virgin Resource saving)
- Reduced amount of limestone extraction and handling
- Less raw material transport to the factory premises
- Less process emissions (from calcination)

2. Alternative Fuels, mainly biomass residues, municipal solid waste and RDF

Partial substitution of fossil fuels combusted in the kilns is expected to lead to

- Decreased fossil fuel amount used (Virgin resource Saving)
- Less or no fossil fuel transport to the factory premises
- Less emissions from stationary combustion (Avoided fossil fuel stationary combustion Emissions)

3. Waste CKD recycling or used in other industries, thus no landfilling
 - Decreased Amount of CKD disposal (Amount saving, thus resource saving)
 - Less land needed for landfilling (Land resource saving)
 - No Mobile combustion emissions resulting from transporting to landfill
 - Decreased landfill emissions and leachate resulting from disposal of CKD
4. Comparison of Fuels based on distance
5. Comparison of Raw materials based on distance

6.4. Emissions

6.4.1. Raw Materials Acquisition

Particulate matter (PM and PM-10) are the primary emissions during extraction of raw materials. Especially during quarrying and crushing and raw material storage. (USEPA, 1995)

The model calculates the amount of raw material based on a user entered amount of raw material per tonne clinker and the amount of clinker per year.

The emissions are thus calculated by the model using the total amount of raw material and an emission factor (kg PM /tonne Raw material). Calculations are carried out either based on default values embedded in the model database or site specific user entered values according to the equation below. Database values for raw materials are given in Table 6-1.

$$\text{Emissions} = \text{Total Raw Material Required} \times \text{EF}$$

Where:

$$\text{Emissions} = \text{Mass of Pollutant emitted}$$

EF = Pollutant emission factor per tonne of Raw material extracted and processed

Calculation logic is depicted in figure 6-3.

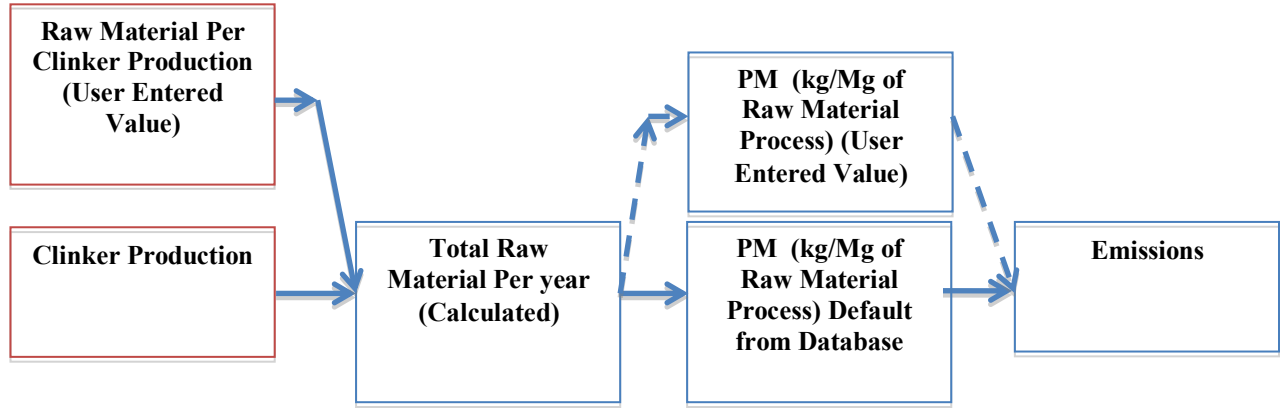


Figure 6-3: Raw Material Extraction and Handling Model Calculation Logic

Table 6-1: Manufacturing Raw Material and Product Processing and Handling

Process and Technology	Unit	Amount of PM matter
Raw Mill		
With Fabric Filter	kg/Mg of Material Process	0.0062
With Feed Belt with Fabric Filter	kg/Mg of Material Process	0.0016
With Weigh Hopper with Fabric Filter	kg/Mg of Material Process	0.01
With Air Separator with Fabric Filter	kg/Mg of Material Process	0.016
Finish Grinding mill		
With fabric filter	kg/Mg of Material Process	0.0042
Feed belt with fabric filter	kg/Mg of Material Process	0.0012
Weigh hopper with fabric filter	kg/Mg of Material Process	0.0047
Air separator with fabric filter	kg/Mg of Material Process	0.014
Primary Limestone		
Crushing with fabric filter	kg/Mg of Material Process	0.0005
Screening with fabric filter	kg/Mg of Material Process	0.00011
Transfer with fabric filter	kg/Mg of Material Process	0.000015
Secondary limestone		
Screening and crushing with fabric filter	kg/Mg of Material Process	0.00016

Source : (USEPA, 1995)

Table 6-2: Emissions Resulting From Blasting Operations

Pollutant	Value	Unit	Source	Link	Reference
NMVOC	9.6	g/ton	Expert judgment presented in the Switzerland IIR 2011	cdr.eionet.europa.eu/	http://www.apec-library.fi
NO _x	3.7	g/ton	Expert judgment presented in the Switzerland IIR 2012	cdr.eionet.europa.eu/	http://www.apec-library.fi
SO _x	0.16	g/ton	Expert judgment presented in the Switzerland IIR 2013	cdr.eionet.europa.eu/	http://www.apec-library.fi
CO	22	g/ton	Expert judgment presented in the Switzerland IIR 2014	cdr.eionet.europa.eu/	http://www.apec-library.fi

6.4.2. Stationary Combustion of Fuels

Stationary fuel combustion in the cement industry mainly occurs in kilns that combust solid, liquid, or gaseous fuel, to produce heat to raise temperatures for the calcination or pyro processing stage.

Fuel combustion produces numerous emissions that can reach harmful concentrations to humans and to the environment. Green house gases such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) constitute the majority of these emissions, with carbon dioxide (CO₂) accounting for the biggest share of the emissions. CO₂ therefore, represents over 99 percent of the total Global Warming Potentials (GWPs) from stationary combustion of fossil fuels. (Gillenwater, 2005)

The model uses clinker production entered by the user and the energy required per ton of clinker (Energy units) to calculate the total energy required for clinker production in GJ/yr. The user has the option of using the default

database value of 3.9 GJ/t Clinker or to a site-specific production value. Using the database of emission values, pollutant / GJ fuel and the total energy required, the amount of pollutant is calculated in tonnes.. Emission factors that are based on energy units are preferred to those per mass or volume units as they are less variable than factors per mass or volume units because the carbon content of a fuel is more closely related to the heat content of the fuel than to the total physical quantity of fuel. Emission factors used for fossil fuels are shown in the Table 6-3 below. The user however, is always encouraged to use site-specific data whenever possible. The model gives the user the flexibility to change any value or some values.

Table 6-3: Pollutant Emission Factors For Conventional Fuels Combustion

Pollutant Emission Factors from Conventional Fuels Combustion								
Pollutant	Unit	Fuel Oil	Natural Gas	Coke	Anthracite Coal	Bituminous Coal	Sub-bituminous Coal	Lignite
*CH ₄	g / GJ	3.0	1.1		11.6	11.6	11.6	11.6
*N ₂ O	g / GJ	0.6	0.1		1.7	1.7	1.7	1.7
*CO ₂	kg /GJ	77.4	52.7	120.0	109.4	98.7	102.5	101.8
*CO								
**NO _x	g/GJ	14.2	89.0	209.0	209.0	209.0	209.0	209.0
**NMVOC	g/GJ	2.3	2.6	1.0	1.0	1.0	1.0	1.0
**SO _x	g/GJ	495.0	0.3	820.0	820.0	820.0	820.0	820.0
**TSP	g/GJ	35.4	0.9	11.4	11.4	11.4	11.4	11.4
**PM ₁₀	g/GJ	25.2	0.9	7.7	7.7	7.7	7.7	7.7
**PM _{2.5}	g/GJ	19.3	0.9	3.4	3.4	3.4	3.4	3.4
**BC	% of PM _{2.5}	5.6	2.5	2.2	2.2	2.2	2.2	2.2
**Pb	mg/GJ	4.6	0.0	7.3	7.3	7.3	7.3	7.3
**Cd	mg/GJ	1.2	0.0	0.9	0.9	0.9	0.9	0.9
**Hg	mg/GJ	0.3	0.1	1.4	1.4	1.4	1.4	1.4
**As	mg/GJ	4.0	0.1	7.1	7.1	7.1	7.1	7.1
**Cr	mg/GJ	2.6	0.0	4.5	4.5	4.5	4.5	4.5
**Cu	mg/GJ	5.3	0.0	7.8	7.8	7.8	7.8	7.8
**Ni	mg/GJ	255.0	0.0	4.9	4.9	4.9	4.9	4.9
**Se	mg/GJ	2.1	0.0	23.0	23.0	23.0	23.0	23.0
**Zn	mg/GJ	87.8	0.0	19.0	19.0	19.0	19.0	19.0
**PCDD/F	ng I-TEQ/GJ	2.5	0.5	10.0	10.0	10.0	10.0	10.0
**Benzon (b)fluranthene	µg/GJ	4.5	0.8	0.7	0.7	0.7	0.7	0.7
**Benzon (k)fluranthene	µg/GJ	4.5	0.8	37.0	37.0	37.0	37.0	37.0
**Indeno(1,2,3-cd)pyrene	µg/GJ	6.9	0.8	29.0	29.0	29.0	29.0	29.0
**Benzon (a)fluranthene			0.6	1.1	1.1	1.1	1.1	1.1
**HCB				6.7	6.7	6.7	6.7	6.7
**PCB				3.3	3.3	3.3	3.3	3.3
**Benzon (a)pyrene								

* Source:

**Source: (Trozzi & Kuenen 2013).

Total Amount of Energy required = Amount of Clinker x Energy /Clinker
Production

Emissions = Total Energy Required x EF

Where:

Emissions = Mass of Pollutant emitted

EF = Pollutant emission factor per energy unit for Fuel type

To calculate emissions from waste fuels, or alternative fuels, the user is asked to enter the type of fuel, and based on the choice, the model selects the corresponding net calorific value, GJ/t fuel. Default calorific values used in the model are shown in Table 6-4 and 6-5.

Table 6-4 : Default Net Calorific Values Database for Fossil Fuels

	NCV	Unit
Fuel Oil	42.24819937	GJ/t
Natural Gas	0.040239664	GJ/m3
Coke	26.185576	GJ/t
Anthracite Coal	26.4917783	GJ/t
Bituminous Coal	26.3228391	GJ/t
Sub-bituminous Coal	18.2137575	GJ/t
Lignite	15.0039127	GJ/t

Table 6-5: Default Net Calorific Values Database for Alternative Fuels

Net Calorific Values for Alternative Fuels		
	NCV	Unit
Tree trimmings	16.471572	GJ/t
Cotton stalks	16.049224	GJ/t
Rice straw	13.515136	GJ/t
Corn stalks	14.359832	GJ/t
Sugar cane trash	15.626876	GJ/t
Wheat	16.47	GJ/t
MSW (IPCC)	10	GJ/t
Raw Rejects “Class C”	12.67044	GJ/t
Un-Shredded RDF “Class B	19.00566	GJ/t
Fluff RDF – “Class A”	23.22914	GJ/t

Using the total energy required for clinker production, GJ/yr, the model calculates the amount of waste material required for the specific amount of clinker per year. To calculate emissions, the model uses the database of emission factors, pollutant/t waste material, listed in Table 6-5 and the amount of waste to calculate the amount of pollutant/ t.

$$\text{Emissions} = \text{Fuel} \times \text{EF}$$

Where:

Emissions = Mass of Pollutant emitted

Fuel = Mass or volume of fuel combusted

EF1 = Pollutant emission factor per mass or volume unit

Table 6-6: Pollutant Emission Factors from Incineration of Agricultural (Assumed to be equivalent to burning in kilns)

Pollutant Emission Factors from Incineration of Agricultural Residues (Equivalent to burning in Kilns)							
Pollutant	Unit	Tree trimmings	Cotton stalks	Rice straw	Corn stalks	Sugar cane trash	Wheat
CH ₄	mg/t dry matter	1.42E+04	1.38E+04	1.16E+04	1.24E+04	1.35E+04	1.42E+04
N ₂ O	mg/t dry matter	8.78E+03	8.56E+03	7.21E+03	7.66E+03	8.33E+03	8.78E+03
CO ₂	mg/t dry matter	1.32E+08	1.28E+08	1.08E+08	1.15E+08	1.25E+08	1.32E+08
NO _x	mg/t dry matter	4.05E+05	3.95E+05	3.33E+05	3.53E+05	3.85E+05	4.05E+05
CO	mg/t dry matter	2.40E+05	2.34E+05	1.97E+05	2.09E+05	2.28E+05	2.40E+05
NM VOC	mg/t dry matter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SO _x	mg/t dry matter	1.69E+04	1.65E+04	1.39E+04	1.47E+04	1.60E+04	1.69E+04
TSP	mg/t dry matter	1.15E+04	1.12E+04	9.42E+03	1.00E+04	1.09E+04	1.15E+04
PM ₁₀	mg/t dry matter	1.55E+05	1.51E+05	1.27E+05	1.35E+05	1.47E+05	1.55E+05
PM _{2.5}	mg/t dry matter	4.39E+04	4.28E+04	3.60E+04	3.83E+04	4.17E+04	4.39E+04
BC	% of PM _{2.5}	3.5	3.5	3.5	3.5	3.5	3.5
Pb	mg/t dry matter	6.69E+02	6.52E+02	5.49E+02	5.83E+02	6.34E+02	6.69E+02
Cd	mg/t dry matter	2.77E+00	2.70E+00	2.27E+00	2.41E+00	2.63E+00	2.77E+00
Hg	mg/t dry matter	2.36E+00	2.30E+00	1.94E+00	2.06E+00	2.24E+00	2.36E+00
As	mg/t dry matter	1.49E+01	1.45E+01	1.22E+01	1.30E+01	1.41E+01	1.49E+01
Cr	mg/t dry matter	1.42E+01	1.38E+01	1.16E+01	1.24E+01	1.35E+01	1.42E+01
Cu	mg/t dry matter	3.31E+01	3.23E+01	2.72E+01	2.89E+01	3.14E+01	3.31E+01
Ni	mg/t dry matter	2.23E+01	2.17E+01	1.83E+01	1.94E+01	2.11E+01	2.23E+01
Se	mg/t dry matter	1.89E+00	1.84E+00	1.55E+00	1.65E+00	1.79E+00	1.89E+00
Zn	mg/t dry matter	2.84E+02	2.76E+02	2.33E+02	2.47E+02	2.69E+02	2.84E+02
PCDD/F	µg I/TEQ t	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(a)fluoranthene	mg/t dry matter	6.76E-02	6.58E-02	5.54E-02	5.89E-02	6.41E-02	6.75E-02
Benzo(k)fluoranthene	mg/t dry matter	2.43E-02	2.37E-02	2.00E-02	2.12E-02	2.31E-02	2.43E-02
Indeno(1,2,3-cd)pyrene	mg/t dry matter	5.88E-02	5.73E-02	4.82E-02	5.12E-02	5.58E-02	5.88E-02
Benzo(a)fluoranthene	mg/t dry matter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HCB	mg/t dry matter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PCB	mg/t dry matter	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(a)pyrene	mg/t dry matter	1.76E+00	1.71E+00	1.44E+00	1.53E+00	1.67E+00	1.76E+00
NH ₃		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Source: Adapted from (USEPA, 2003)

Table 6-7: Pollutant Emission Factors from MSW Incineration (Assumed Equivalent to Burning in Kilns)

Pollutant Emission Factors from MSW Incineration (without energy recovery)				
Pollutant	Unit	Municipal Refuse	Note	Source
Methane	kg/TJ	30	Using Calorific value of 10TJ/Gg	* http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf
Nitrous Oxide	kg/TJ	4		
Carbon Dioxide	kg/TJ	91700		
Nitrogen Oxide	kg/Mg waste	1.8		**Guidebook (2006) (as cited in EMEP/EEA emission inventory guidebook 2013) Table 3-2 Tier 2 emission factors for source category 5.C.1.a Municipal waste incineration
Carbon monoxide	kg/Mg waste	0.7		
Non-methane volatile organic compounds	kg/Mg waste	0.02		
Sulfur dioxide	kg/Mg waste	1.7		
Trisodium Phosphate	kg/Mg waste	18.3		
Particulate matter PM10	kg/Mg waste	13.7		
Particulate matter PM2.5	kg/Mg waste	9.2		
BC	% of PM2.5	3.5		
Lead	g/Mg	104		
Cadmium	g/Mg	3.4		
Mercury	g/Mg	2.8		
Arsenic	g/Mg	2.14		
Chromium	g/Mg	0.185		
Copper	g/Mg	0.093		
Nickel	g/Mg	0.12		
Selenium	g/Mg			
Zinc	g/Mg	0.9		
PCDD/F	mg I-TEQ/Mg waste	3.5		
Benzo (b)fluranthene	mg/Mg	3.2		
Benzo (k)fluranthene	mg/Mg	3.1		
Indeno(1,2,3-cd)pyrene	mg/Mg			
Hexachlorobenzene		0.002		
polychlorinated biphenyl	mg/Mg	5.3		
Benzo (a)pyrene	µg/Mg	4.2		
Ammonia	g/Mg	3		

*Source: (IPCC, 2006)

**Source: (Trozzi, 2013)

Table 6-8: Emission Factors for Refuse-Derived Fuel Fired Combustors

Emission Factors For Refuse-Derived Fuel-Fired Combustors (Assumed Equivalent to Combustion in Kilns)						
Pollutant	Unit	Refuse Derived Fuel Emission Factor	Electrostatic Precipitator (ESP)	Spray Dryer/Electrostatic Precipitator(SD/ESP)	Spray Dryer/Fabric Filter (SD/FF)	Link
PM	kg/t	3.48E+01	5.17E-01	4.82E-02	6.64E-02	https://www3.epa.gov/ttnchie1/ap42/c h02/final/c02 s01.pdf
As	kg/t	2.97E-03	6.70E-05	5.41E-06	2.59E-06	
Cd	kg/t	4.37E-03	1.10E-04	4.18E-05	1.66E-05	
Cr	kg/t	6.99E-03	2.34E-04	5.44E-05	2.04E-05	
Hg	kg/t	2.80E-03	2.80E-03	2.10E-04	1.46E-04	
Ni	kg/t	2.18E-03	9.05E-03	9.64E-05	3.15E-05	
Pb	kg/t	1.00E-01	1.84E-03	5.77E-04	5.19E-04	
SO2	kg/t	1.95E+00	ND	7.99E-01	2.21E-01	
HCl	kg/t	3.49E+00	ND	ND	2.64E-02	
NO	kg/t	2.51E+00	ND	ND	ND	
CO	kg/t	9.60E-01	ND	ND	ND	
CO2	kg/t	1.34E+03	ND	ND	ND	
CDD/CDF	kg/t	4.73E-06	8.46E-06	5.31E-08	1.22E-08	

Source: (USEPA, 1996)

In the case of waste fuels, i.e. agricultural waste, municipal waste and RDF, emission factors used are per ton of material. While emission factors per fuel heat content are considered more accurate, it is not always possible as waste is a non-homogeneous substance.

While CO₂ from biomass fuels is calculated in the model, it should be noted that CO₂ is climate-neutral i.e. released gas can be balanced by planting biomass in the short term. CO₂ from biomass is therefore only listed as a “memo”, but not included in the total emissions.

Calculation logic is depicted in figure 6-4.

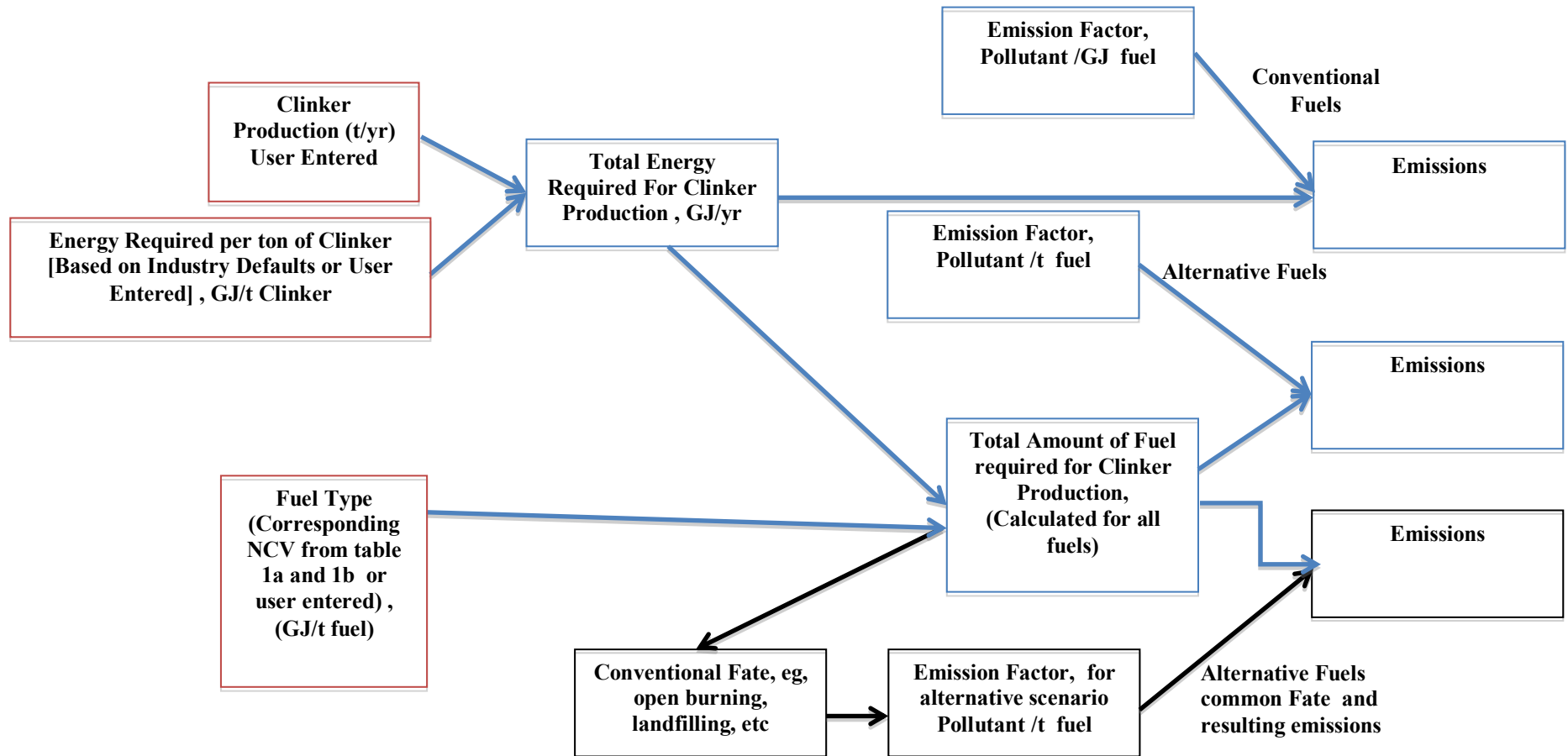


Figure 6-4: Stationary Combustion Emissions for Conventional and Alternative Fuels Calculation Logic

Table 6-9: Amount of Fuel Required per ton of Clinker

Amount of fuel Required per ton of Clinker [Based on Default Values in Tables 6.3 & 6.4]		
	Amount	Unit
Fuel Oil	0.092311626	t
Natural Gas	96.91929722	m3
Coke	0.148936957	t
Anthracite Coal	0.147215485	t
Bituminous Coal	0.14816031	t
Sub-bituminous Coal	0.214123857	t
Lignite	0.259932198	t
Tree trimmings	0.236771572	t
Cotton stalks	0.243002403	t
Rice straw	0.288565354	t
Corn stalks	0.271590921	t
Sugar cane trash	0.249570036	t
Wheat	0.236794171	t

6.4.3. Mobile Combustion

Like in stationary combustion, many emissions occur as a result of combustion of fuels in vehicles. Most pronounced amounts are greenhouse gases CO₂, CH₄, and N₂O that are emitted during the combustion of fuels in mobile sources.

According to GHG Inventory guidance document issued by EPA, CH₄ and N₂O emissions are present in smaller amounts relative to the overall GHG emissions resulting from transportation (approximately one percent combined). For on-road vehicles less than 15 years old, CH₄ and N₂O emissions typically account for one percent of emissions or less.

The transport sub-model calculates emissions resulting from the collection of fuels, both waste or fossil, raw materials and waste CKD to the landfill and any other substance transported to the production premises.

1. Transport of Fuels

The model uses clinker production entered by the user and the energy required per ton of clinker (Energy units) to calculate the total energy required for clinker production in GJ/yr. Using the user entered choice of the fuel type being transported, the model retrieves a value for the corresponding net calorific value and thus calculates the amount required to be transported (t/yr) (which corresponds to the need per year). The user is then required to enter the truck or vehicle capacity from which the model calculates the number of trips required to transport the total amount of fuel. Using the average round trip distance entered by the user, the model calculates the total distance traveled. Using an average fuel consumption per km, the model calculates the total vehicle fuel consumption. The user finally enters the vehicle fuel type from which the database retrieves a net calorific value, GJ/t and consequently calculates emissions using the default emission factors. All default values can be replaced by site specific data if available.

2. Transport of Raw Materials/waste materials

Using user entered amounts of raw material and vehicle load capacity, the model calculates the number of trips. Using the average round trip distance entered by the user, the model calculates the total distance traveled. Using an average fuel consumption per km, the model calculates the total vehicle fuel consumption. The user finally enters the vehicle fuel type from which the database retrieves a corresponding net calorific value, GJ/t and consequently calculates emissions using the default emission factors. All default values can be replaced by site specific data if available.

The structure of the model is depicted in Figures 6-5 to 6-6 below:

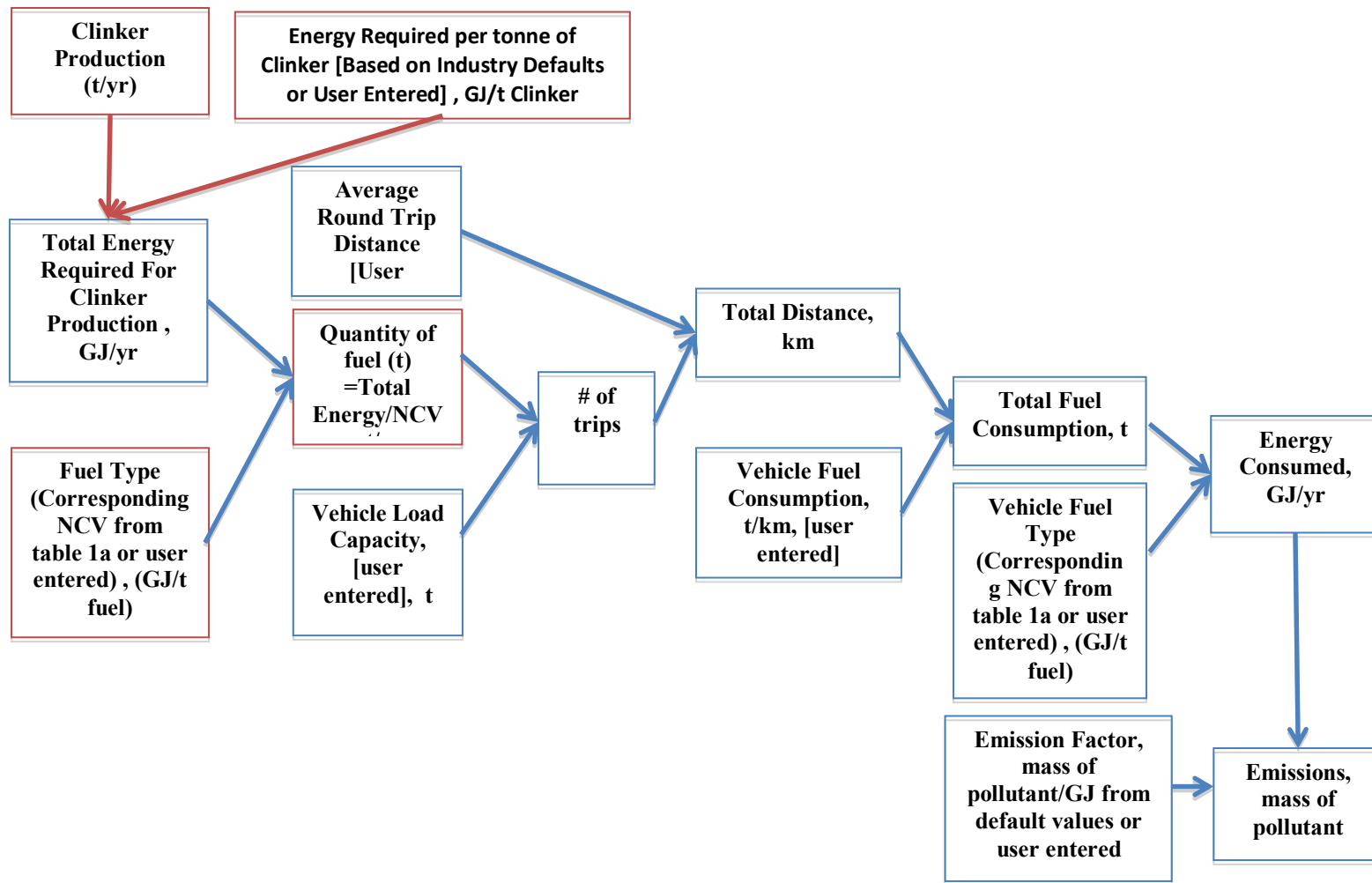


Figure 6-5: Mobile Combustion Emissions (Transport of Fuels to the Plant)

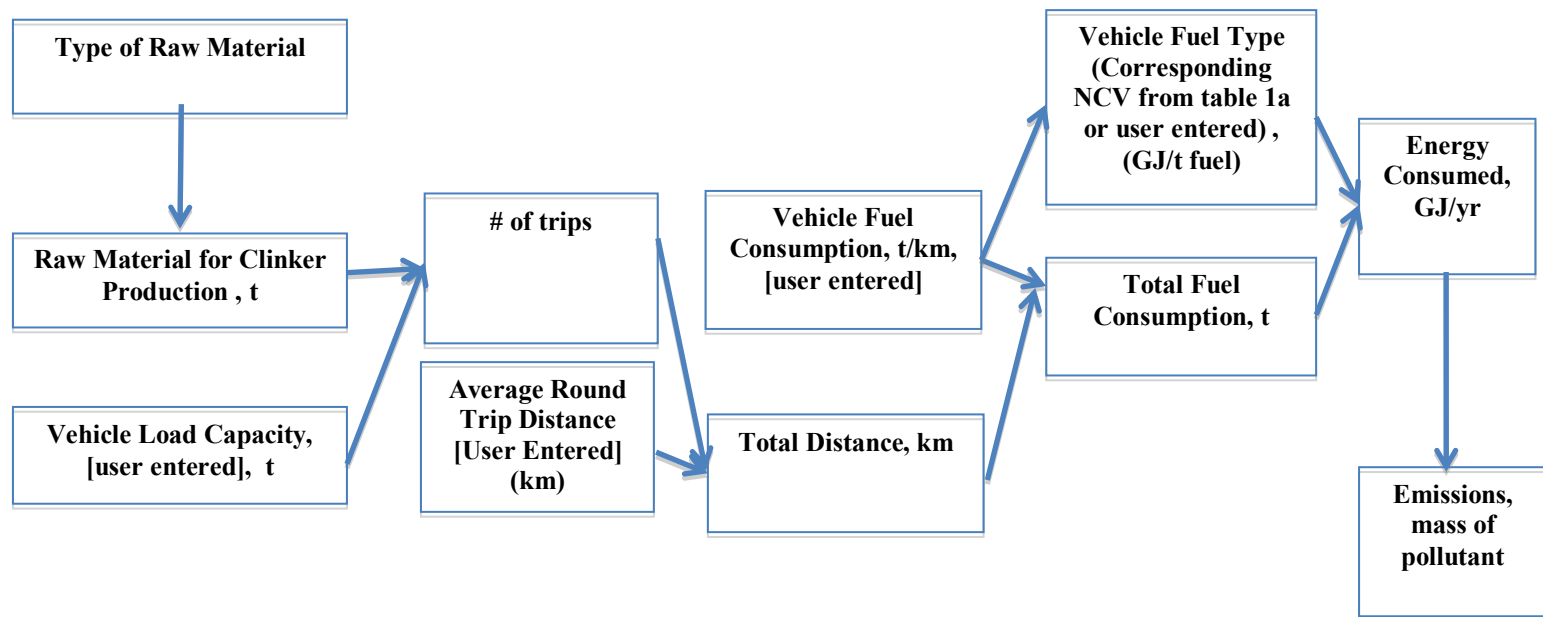


Figure 6-6: Mobile Combustion Emissions (For Transport of Raw Material to the Plant)

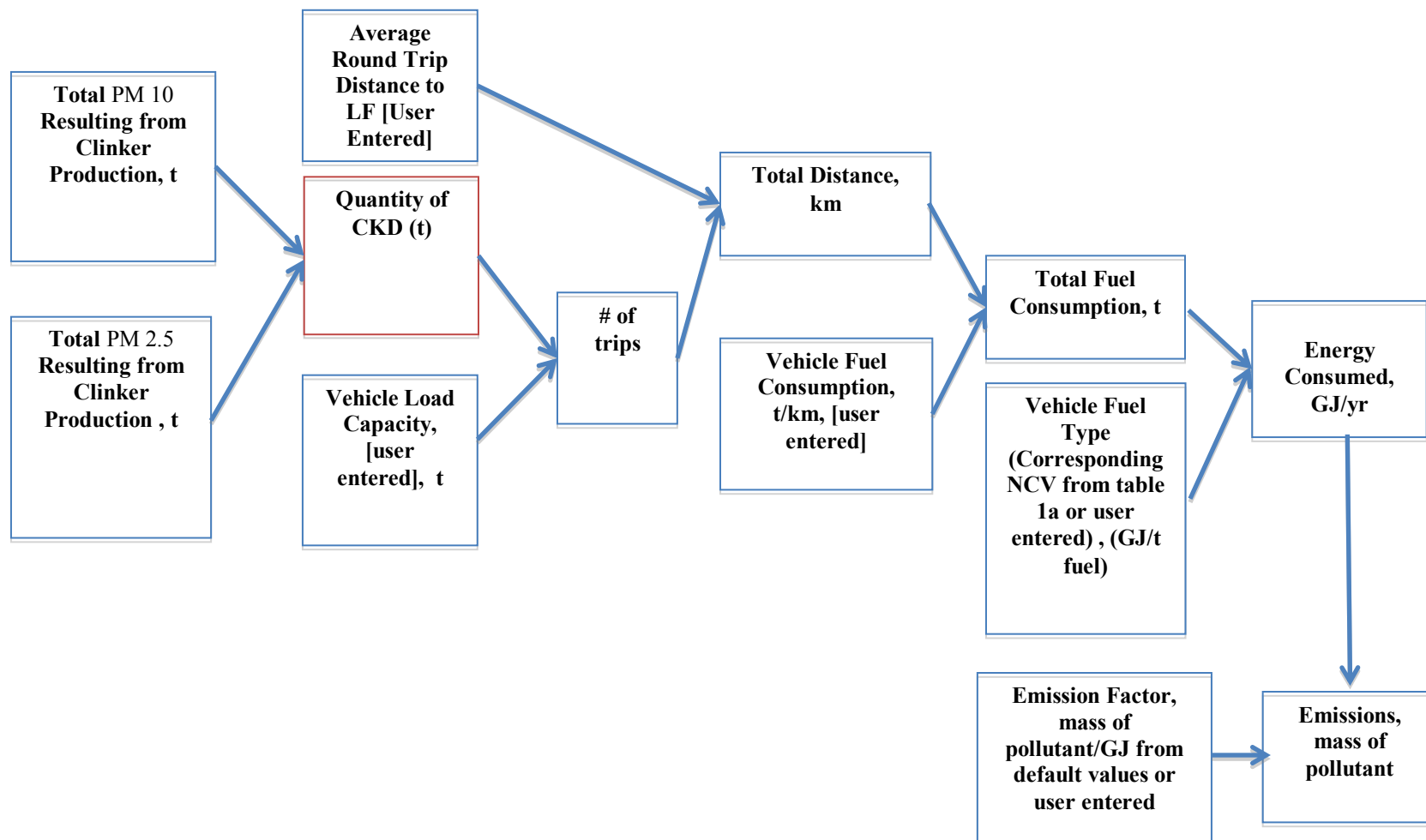


Figure 6-7: Mobile Combustion Emissions (For Disposal of CKD)

6.4.4. Process Emissions

Process emissions in the model are basically calculated in two distinct stages:

1. Carbon Dioxide, the main emission in Clinker production

Carbon dioxide is emitted during the clinker production, a result of a series of complex reaction involving the breakdown of calcium carbonate at high temperatures. (IPCC, 2000). Below is a simplified stoichiometric equation:



The model calculates CO₂ resulting from the calcination process employing the amount of clinker produced and an emission factor of CO₂ per tonne of clinker. The emission factor is determined based on the measured CaO and MgO contents of the clinker entered by the user, and is corrected for any considerable amounts of non-carbonate sources of CaO and MgO in the clinker. An example of this situation stems if mineral calcite raw materials added to the kiln are substituted by calcium silicates or fly ash (since these materials do not undergo a calcination process and do not contribute to carbon dioxide emissions).

The emission factor for clinker is calculated using the equation below: of the fraction of lime in the clinker multiplied by the ratio of the mass of CO₂ released per unit of lime. This is illustrated below (IPCC, 2000):

$$\text{EF clinker} = \text{fraction CaO} \times \text{Mass CO}_2 / \text{Mass CaO} \text{ (44.01 g CO}_2 \text{ / 56.08 g/mole CaO)}$$

Where:

$$\text{Fraction CaO} = \text{Fraction of lime in the Clinker}$$

$$\text{Multiplication Factor} = \frac{\text{Mass CO}_2}{\text{Mass CaO}} \\ = \text{Molecular weight ratio of CO}_2 \text{ to CaO}$$

Since most of the calcium oxide in clinker comes from a calcium carbonate source, the multiplication factor is the “molecular weight ratio of CO₂ to CaO in the raw material mineral calcite (CaCO₃)”.

In the absence of actual values, the model default of 525 kg CO₂/t clinker is automatically used for model calculations. (IPCC, 2000)

Table 6-10: Process Emissions Parameters, Units and Proposed source of Parameters

Emission components	Parameters	Units	Proposed source of parameters
Raw materials:			
Calcination of clinker	Clinker produced	Tones, t	Measured
	CaO + MgO in clinker	%	Measured
	CaO + MgO in raw meal	%	Measured
Calcination of dust	Dust leaving kiln	t	Measured
	Emission factor clinker	t CO ₂ / t cli	As calculated above
	Dust calcination degree	% calcined	Measured
Organic carbon in raw materials	Clinker	t cli	Measured
	Raw meal : clinker ratio	t/ t cli	Default = 1.55; can be adjusted
	TOC content of raw meal	%	Default = 0.2%; can be adjusted
Fuel combustion:			
Conventional kiln fuels	Fuel consumption	t	Measured
	Lower heating value	GJ /t fuel	Measured
	Emission factor	t CO ₂ /GJ fuel	IPCC defaults, or measured
Alternative fossil fuels(fossil AF)	Fuel consumption	t	Measured at plant level
	Lower heating value	GJ /t fuel	Measured
	Emission factor	t CO ₂ /GJ fuel	Default values, or measured
Biomass fuels (biomass AF)	Fuel consumption	t	Measured
	Lower heating value	GJ /t fuel	Measured
	Emission factor	t CO ₂ /GJ fuel	Default values or measured
t = metric tonne, AF = Alternative fuels, cli = clinker, TOC = Total organic carbon			

Source: (Initiative, C. S., 2005)

Table 6-11: Emission Factors for Process Emissions

	Filterable		Condensable		Sulfur dioxide (SO ₂) (kg/t clinker)	Nitrogen oxides (NO _x) (kg/t clinker)	Carbon Monoxide (CO) (kg/t clinker)	TOC (kg/t clinker)
	PM (kg/t clinker)	PM-10 (kg/t clinker)	Inorganic (kg/t clinker)	Organic (kg/t clinker)				
Dry Process Kiln								
with ESP	0.5	0	0.19	0	4.9	3	0.11	0.014
with fabric filter	0.1	0.084	0.45	0	4.9	3	0.11	0.014
Preheater Kiln								
Preheater/precalciner with fabric filter process kiln	0.1	ND	ND	ND	0.54	2.1	1.8	0.059
Preheater kiln	130	ND	ND	ND	0.27	2.4	0.49	0.09
Preheater kiln with ESP	0.13	ND	ND	ND	0.27	2.4	0.49	0.09
Preheater kiln with fabric filter	0.13	ND	0.017	ND	0.54	2.1	1.8	0.059
Preheater/precalciner kiln with ESP	0.024	ND	ND	ND	0.54	2.1	1.8	0.059
Preheater/precalciner with PM controls	ND	ND	0.078	ND	0.54	2.1	1.8	0.059
Clinker Cooler								
with ESP	0.048	ND	0.0038	ND	0	0	0	0
with fabric filter	0.068	ND	0.0084	ND	0	0	0	0
with gravel bed filter	0.11	0.084	0.0045	ND	0	0	0	0

Source: (USEPA, 1995)

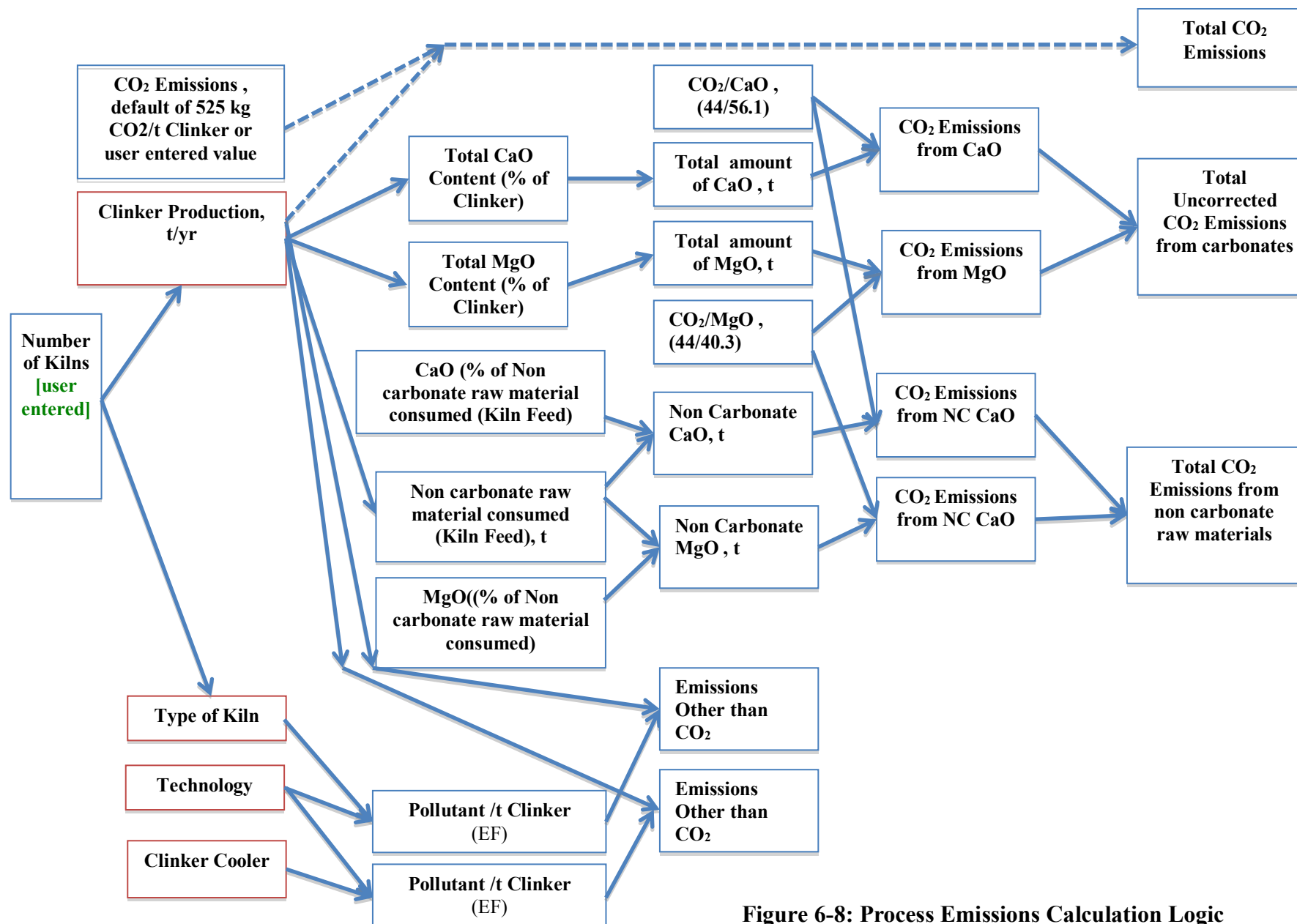


Figure 6-8: Process Emissions Calculation Logic

6.5. Material and Energy

1. Energy Recovery

The energy recovery sub-model calculates energy produced by different fuels, including energy from waste options and compares between the amounts provided using the net calorific values for each and the total energy required for clinker production. It is possible for the user to carry out the comparison between different types of wastes in addition to fossil fuels. It also addresses possible heat recovery options from calcination and converts them to corresponding savings in amounts of virgin material used.

2. Natural Resource Conservation

The model assumes that all waste materials consumed replace their virgin raw material equivalents. In other words, if 10 tons of biomass is combusted to produce an amount of energy that would otherwise be given by 6 tons of coal, then the 6 tons of virgin resource coal is conserved.

6.6. Comparisons and sensitivity analysis

Alternative fuels (AF) in the cement industry provide good substitutes to conventional fuels and usually come from wastes. These wastes would have otherwise been disposed of in landfills or burned in incinerators. The sensitivity analysis aims at doing two things:

1. Carry out a “what if Analysis” to get to conclusions on the best scenario.

Alternatives may sometimes for example prove less beneficial if for example, mobile emissions are high as a result of the distance they originate from.

2. Calculate both induced, avoided and net emissions as a result of
 - a. Partial or complete fuel switching (avoided emissions from fossil fuels in addition to avoided impacts from disposal of alternative fuels in the conventional way.
 - b. recycling or selling waste CKD verses disposing,
 - c. avoided or reduced material resource use as a result of reducing clinker production

Table 6-12: Impact of Production Stage on Impact Category

		Production Stage																		
		Upstream							Process								Downstream			
		Raw Materials Quarrying	Raw Materials Processing	Raw Materials Preparation	Raw Material Mixing and Blending	Finished Raw Material	Recycled Waste	Raw Material Transportation	Raw Feed Mix	Preheater/Precalciner Kiln	Rotary Kiln	Clinker Cooler	Final Clinker	Clinker Storage	Finish Grinding Mill	Air Separator	Product Packaging	Product Storage	Final Product	Final Product Transportation
Impact Category	Virgin Materials in Nature (Amount)	-						-		-	-		-				-			-
	Waste	+	+	+	+		-	+	□	+	+	+	□		+					+
	Waste Material Recycled into Process	-	-	-	-	-							✓				✓			
	Transportation					✓	✓	□											✓	□
	Electricity	✓	✓	✓	✓	✓	✓	□	✓	✓	✓	✓			✓	✓				
	Fossil Fuels	✓	✓	✓	✓	✓	✓	□												
	Water																			
	Carbon dioxide (CO2)							✓		✓	✓									✓
	Methane (CH4)																			
	Nitrous oxide (N2O)							✓		✓	✓									✓
	Ozone (O3)																			
	Chlorofluorocarbons (CFCs)																			
	PM 2.5	✓	✓	✓	✓	□	□	□	✓	✓	✓	✓	✓	□	□	✓				
	PM 10	✓	✓	✓	✓	□	□	□	✓	✓	✓	✓	✓	□	□	✓				
	Other Priority Non GHG Pollutants																			

6.7. Assumptions and Limitations

1. All calcium carbonate was assumed to undergo full calcination disregarding CKD. This results in an overestimation of CO₂ emissions unless the dust is 100% calcinated.
2. While biomass is only considered climate-neutral if sustainably harvested, it is always assumed so in the model, regardless of the method of harvesting.
3. Default values for emission factors are obtained from international sources like EPA's AP-42 and the Danish EMEP Inventory guidebook, rather than local values. While efforts were made bring values close to the actual, eg by using proportionality between local heating values and those reported or carbon content whenever local data was available, values may, at times not align with local situations .
4. Imports of Clinker are not considered in the calculations
5. Mobile combustion in the model refers to road transport, i.e vehicles like trucks, tankers, etc.. While other types of transportation may be used in cases of imports, they were excluded from the calculations for simplicity.

6.8. Inventory Quality

Default values for emission factors are obtained from international sources like EPA's AP-42 and the Danish EMEP Inventory guidebook, and rarely from local sources. While trials were made to make the values more realistic, eg by using proportionality between heating values or carbon content whenever local data was available, results may not always represent actual situations.

It should also be noted that data was collected from many different sources from several countries. While all sources are considered reliable listings, materials tested may exhibit variations in composition from one region to another and the testing procedure itself may be different. Comparison therefore may turn unrealistic results at times. The user is therefore advised to use site-specific data whenever possible and exercise caution when using default.

CHAPTER 7 : MODEL INTERFACE, CALCULATIONS AND EXTRACTS

CHAPTER 7

MODEL INTERFACE AND CALCULATIONS

This chapter displays the application of the computational framework using the approaches and techniques proposed in the previous chapter. Extracts from model interfaces are presented.

7.1. Baseline Scenario Emissions

Figure 7-1 is the general process information interface. The user chooses one of two options, either to start a new process or to load a previous process. To start a new process, a name, clinker output amount, cement to clinker ratio and kiln dust control method is entered for the process line.

Once the start button is selected, the user is taken to the process emissions page, Figure 7-2, where a display of the default emission factors (kg pollutant per tonne clinker) from the database is shown and the total amount of emission for each pollutant is calculated. These are the calculations of the calcination process in kilns.

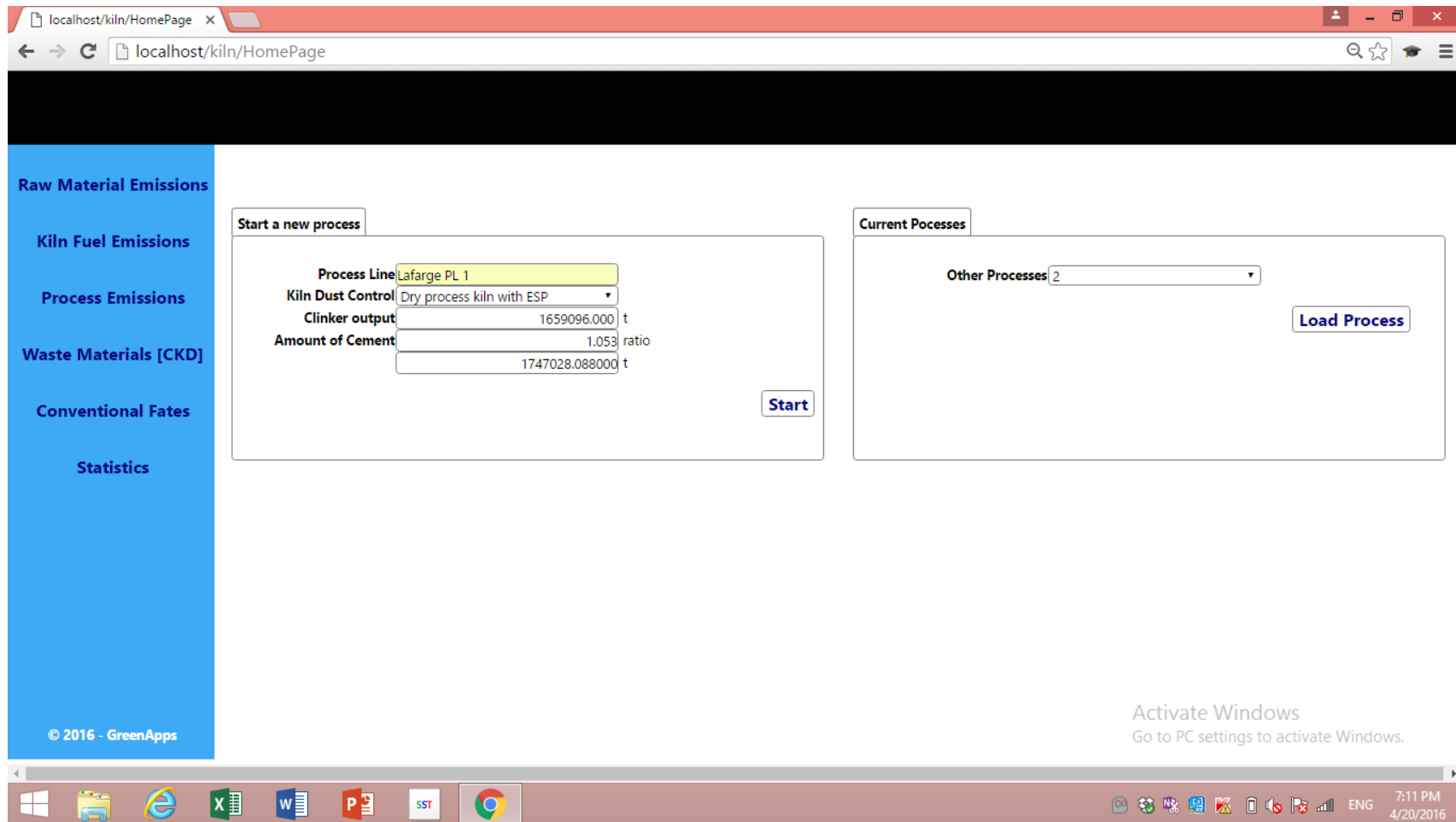


Figure 7-1: General Process Information Interface

localhost/kiln/ProcessEmissions

Process Line Lafarge PL 1
Kiln Dust Control Dry process kiln with ESP

Clinker output 1659096.000 t
Cement Amount 1747028.0880000000 t

New Process Copy Process
Delete Process History

Other Processes 2
Load Process

Raw Material Emissions
Kiln Fuel Emissions
Process Emissions
Waste Materials [CKD]
Conventional Fates
Statistics

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Process Kiln Emissions

Pollutant /t	PM	PM-10	Inorganic	Organic	SO2	NOx	CO	TOC
Amount	829548.000	0.0000000	315228.240	0.0000000	8129570.40	4977288.00	182500.560	23227.3440 kg

Total CO2 Emissions

Default Factor 525.0000 kg CO2/t
Total CO2 Emissions 871025400.0000000 kg

Total Uncorrect CO2 Emissions from carbonates

	%	Amount	Factor	CO2 Emissions
CaO	65.0000	1078412.40	1.0000	1078412.40 t
MgO	2.0000	33181.9200	1.0000	33181.9200 t

Total CO2 Emissions from non carbonate raw materials

Slag 0.0000 t

	%	Amount	Factor	CO2 Emissions
CaO	0.0000	0.00000000	0.7840	0.00000000 t
MgO	0.0000	0.00000000	1.0920	0.00000000 t

Activate Windows
Go to PC settings to activate Windows.

7:12 PM
4/20/2016

Figure 7-2: Preheater and Clinker Cooler Emissions

localhost/kiln/ProcessEmissions

Process Line: Lafarge PL 1
Kiln Dust Control: Dry process kiln with ESP

Clinker output: 1659096.000 t
Cement Amount: 1747028.0880000000 t

New Process Copy Process
Delete Process History

Other Processes: 2
Load Process

Raw Material Emissions
Kiln Fuel Emissions
Process Emissions
Waste Materials [CKD]
Conventional Fates
Statistics

Total CO2 Emissions

Default Factor: 525.0000 kg CO2/t
Total CO2 Emissions: 871025400.0000000 kg

Total Uncorrect CO2 Emissions from carbonates

	%	Amount	Factor	CO2 Emissions
CaO	65.0000	1078412.40	1.0000	1078412.40 t
MgO	2.0000	33181.9200	1.0000	33181.9200 t

Total CO2 Emissions from non carbonate raw materials

Slag: 0.0000 t

	%	Amount	Factor	CO2 Emissions
CaO	0.0000	0.00000000	0.7840	0.00000000 t
MgO	0.0000	0.00000000	1.0920	0.00000000 t

Pre-Heater & Cooler Emissions

Add New

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Activate Windows
Go to PC settings to activate Windows.

Windows Taskbar: 7:14 PM 4/20/2016

Figure 7-3: Preheater and Clinker Cooler Emissions

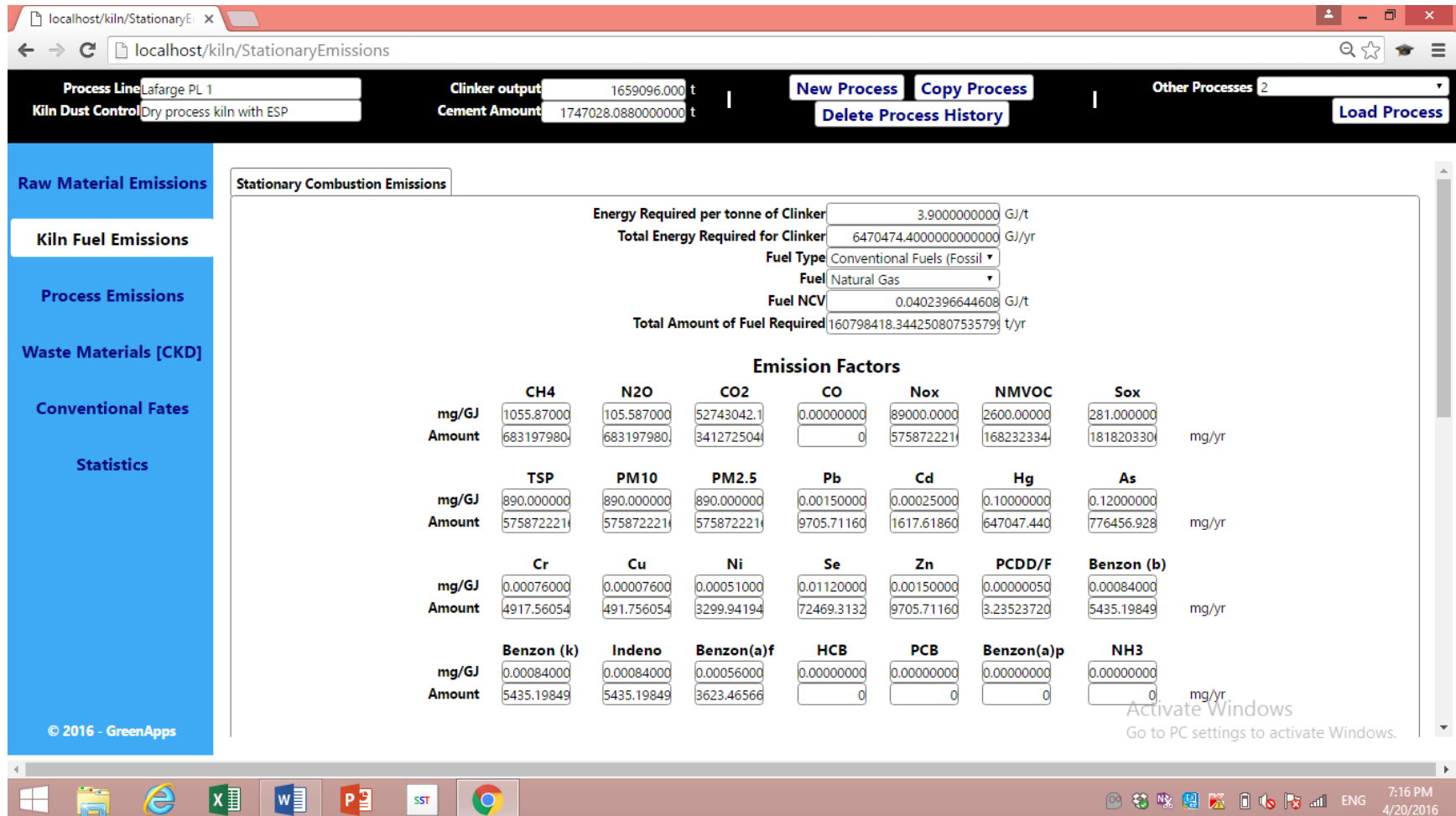


Figure 7-4: Kiln Fuel Stationary Emissions

localhost/kiln/StationaryEmissions

Process Line: Lafarge PL 1
Kiln Dust Control: Dry process kiln with ESP

Clinker output: 1659096.000 t
Cement Amount: 1747028.0880000000 t

New Process Copy Process
Delete Process History Load Process

Other Processes: 2

Raw Material Emissions
Kiln Fuel Emissions
Process Emissions
Waste Materials [CKD]
Conventional Fates
Statistics

Mobile Combustion Emissions

Total Amount of Fuel required: 160798418.344250807535799 t/yr
Vehicle Capacity: 10.0000000000 t
of trips: 16079842
Average Trip Distance: 30 km
Total Distance: 482395260 km
Vehicle Fuel Consumption: 0.0003514800 t/km
Total Fuel Consumption: 339104.5719696000 t
Fuel Type: Conventional Fuels (Fossil)
Fuel: Fuel Oil
Fuel NCV: 42.2481993654822 GJ/t
Energy Consumed: 14326557.562318167743907 GJ/yr

Emission Factors

	CH4	N2O	CO2	CO	Nox	NMVOC	Sox	
mg/GJ	3000.00000	600.000000	77400000.0	0.00000000	14200.0000	2300.00000	495000.000	
Amount	429796726	859593453	110887555	0	203437117	329510823	709164599	mg/yr

	TSP	PM10	PM2.5	Pb	Cd	Hg	As	
mg/GJ	35400.0000	25200.0000	19300.0000	4.56000000	1.20000000	0.34100000	3.98000000	
Amount	507160137	361029250	276502560	65329102.4	17191869.0	4885356.12	57019699.0	mg/yr

	Cr	Cu	Ni	Se	Zn	PCDD/F	Benzon (b)	
mg/GJ	2.55000000	5.31000000	255.000000	2.06000000	87.8000000	0.00000250	0.00450000	
Amount	36532721.7	76074020.6	365327217	29512708.5	125787175	35.8163939	64469.5090	mg/yr

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Figure 7-5: Kiln Fuel Mobile Emissions

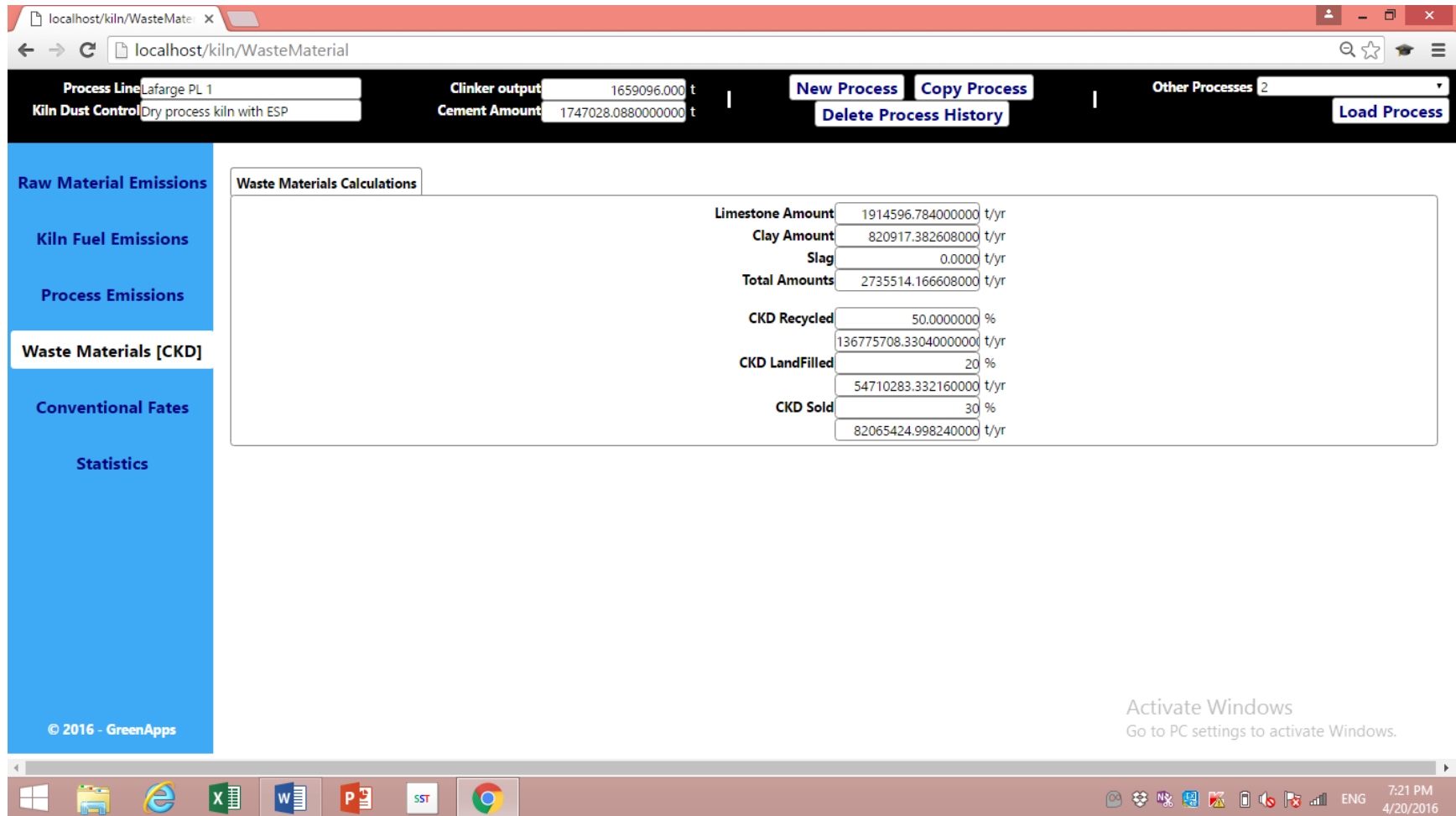


Figure 7-6: Cement Kiln Dust

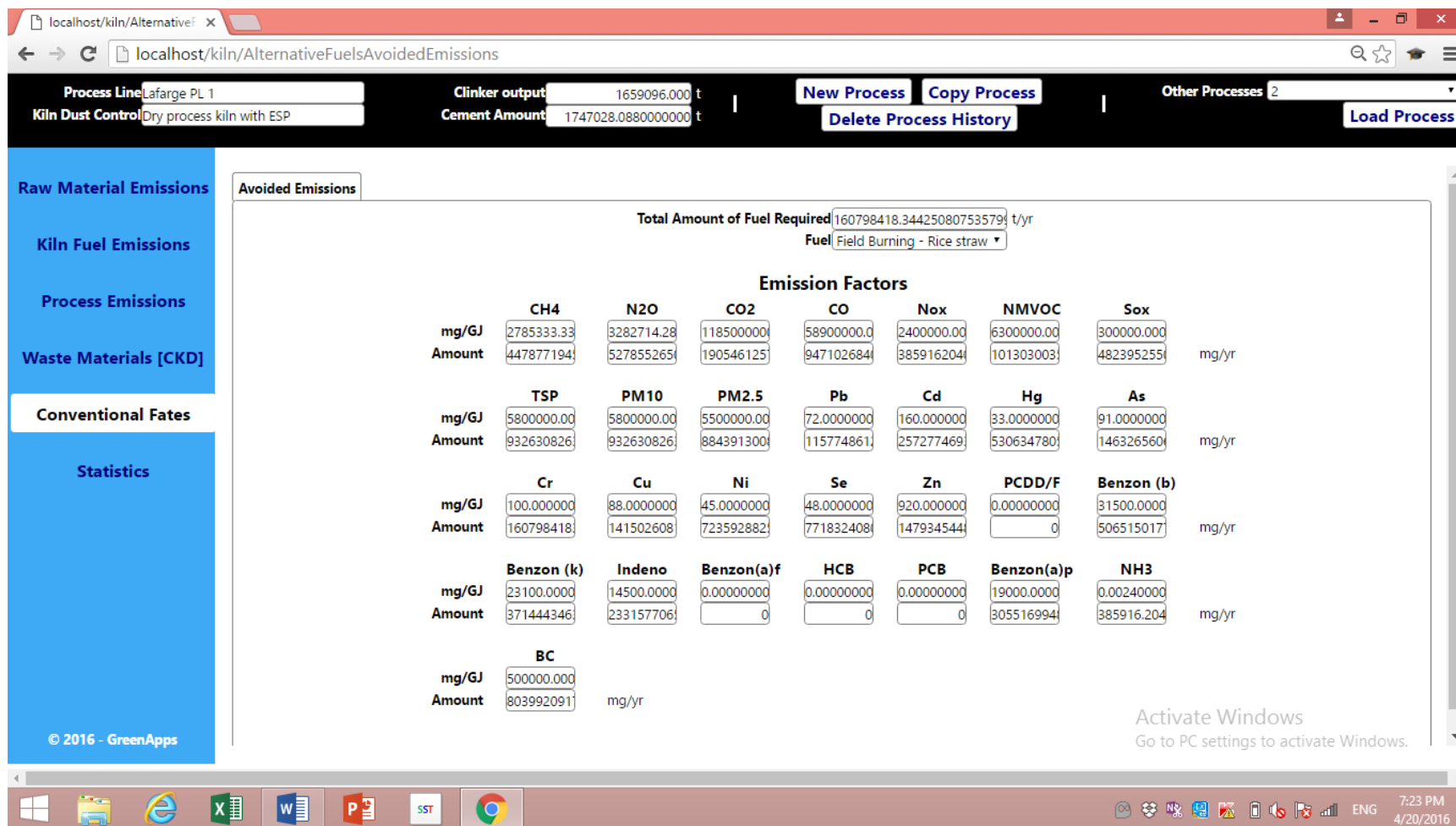


Figure 7-7: Conventional Wastes Fate

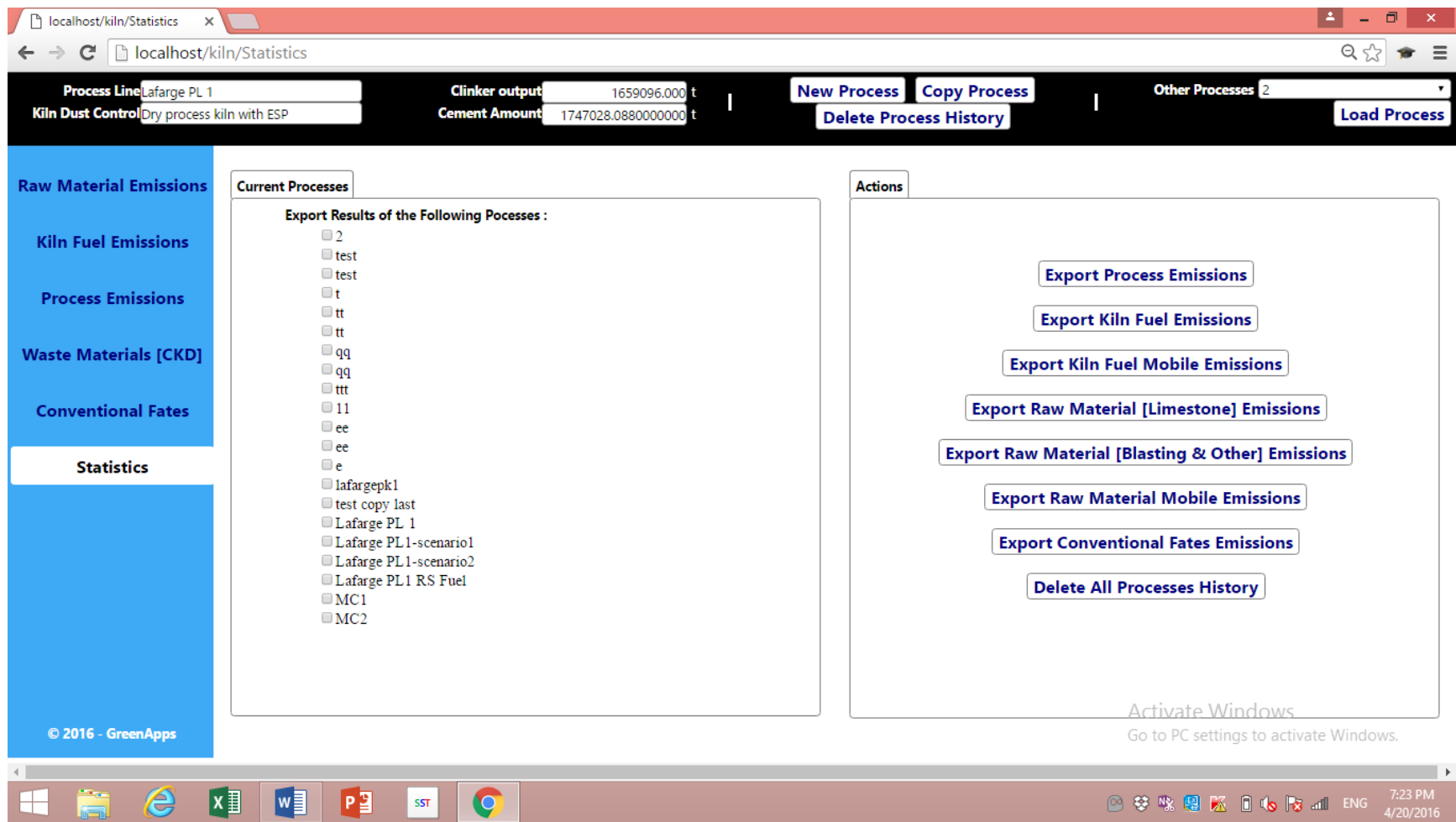


Figure 7-8: Calculation Summary

If the user chooses to add a number of preheater and clinker cooler units, the model loads the applicable emission factors from the database and uses the values to calculate the resulting emission amounts as made for the process kiln.

The kiln fuel emissions are the emissions resulting from the burning of fuels. These are handled in the "kiln fuel emissions" interface. This interface calculates emissions from two sources, stationary combustion of the fuels in the kilns and mobile combustion of fuels transported to the facility.

Once the user opens the "kiln fuel emissions" tab, the parameters and default emission values appear on the screen, Figure 7-4. The emissions are calculated depending on the fuel type chosen by the user, its corresponding heating value and the database default emission factors or user entered values. The total amount of fuel is calculated using the fuel heating values and is automatically copied to the mobile combustion part on the same tab to calculate corresponding emissions resulting from the transport of fuels, Figure 7-5.

The model allows for the repeated computation of all the previous calculations of alternative scenarios for comparison purposes. Alternative scenarios incorporated in the model were based on research findings on possible emissions savings in the cement industry. These include kiln fuel substitution, changes in cement clinker ratios, changes in distances of transported materials, recycling or selling of CKD rather than disposal or change in the dust control technology. The user is allowed to copy a process any number of times and choose any of the alternative scenario changes to carry out a comparison.

7.2. Resources Calculations

Baseline scenario resources are the amounts of raw materials, conventional fuels and waste produced in the cement industry. Amounts of raw materials and conventional fuels were calculated as discussed in 8.1 above. The only waste considered to result from the cement industry is cement kiln dust (CKD) and is calculated as a percentage of the total amount of raw material, Figure 8-6. A default of 2 % is used but can be altered if the user wishes. The amounts of recycled CKD, landfilled CKD and sold CKD are also calculated based on user entered percentages. All amounts recycled back to the process are considered raw material savings.

7.3. Avoided Emissions

The model considers all alternative fuel substitutions as ones resulting in avoided emissions that would have occurred in a conventional scenario. This is the case with agricultural residues, municipal solid waste and refuse derived fuel, that in the absence of the project would have gone through open burning or landfilling. The conventional fates tab, Figure 8-7 computes emissions resulting from the fate of the chosen alternative scenario. The amount of material is automatically entered from the kiln fuel emissions tab.

7.4. Resources Savings

All substitutions using waste materials are credited as resource savings. This is the case whenever virgin fossil fuels for instance, or any virgin raw materials are substituted with waste materials. This results in double benefit, elimination of waste and conservation of raw materials.

7.5. Model Outputs

Figures 8-9 through 8-12 are outputs extracts exported to excel and created by the model. The below example compares between 2 scenarios, but the user can create any number of scenarios with many possible combinations.

Process_Line	Unit	CH4	N2O	CO2	CO	Nox	NMVOC	Sox	TSP
Lafarge PL 1	mg/yr	19411423200	3882284640	5.00815E+14		0 91880736480	14882091120	3.20288E+12	2.29055E+11
Lafarge PL1-scenario	mg/yr	5572543716	3449669919	5.1745E+13	1.59216E+11	94202524715		0 6633980614	4511106817

Process_Line	PM10	PM2_5	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCDD_F	Benzon_b	Benzon_k	Indeno
Lafarge PL 1	1.63056E+11	1.2488E+11	29505363	7764569	2206432	25752488	16499710	34358219	1649970972	13329177	568107652	16.17619	29117.13	29117.13	44775.68
Lafarge PL1-sc	60966281840	17248349596	262705632	1087973	928757.3	5837903	5572544	13002602	8756854.41	743005.8	111450874	0	26535.92	9552.932	23086.25

Figure 7-9: Stationary Combustion Kiln fuel emissions

Process_Line	Unit	CH4	N2O	CO2	CO	Nox	NMVOC	Sox	TSP	PM10	PM2_5
Lafarge PL 1	mg/yr	1.9411E+10	3882284640	5.0081E+14		0 9.1881E+10	1.4882E+10	3.20288E+12	2.2905E+11	1.6306E+11	1.2488E+11
Lafarge PL1-scenario1	mg/yr	1.9411E+10	3882284640	5.0081E+14		0 9.1881E+10	1.4882E+10	3.20288E+12	2.2905E+11	1.6306E+11	1.2488E+11

Process_Line	Unit	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	PCDD_F	Benzon_b	Benzon_k	Indeno
Lafarge PL 1	mg/yr	29505363.3	7764569.28	2206431.77	25752488.1	16499709.7	34358219.1	1649970972	13329177.3	568107652	16.176186	29117.1348	29117.1348	44775.6828
Lafarge PL1-scenario1	mg/yr	29505363.3	7764569.28	2206431.77	25752488.1	16499709.7	34358219.1	1649970972	13329177.3	568107652	16.176186	29117.1348	29117.1348	44775.6828

Figure 7-10: kiln fuel Mobile Combustion (transport)

Process_Line	Linestone (t/yr)	Blasting_NMVOC (mg/yr)	Blasting_NOx (mg/yr)	Blasting_SOx (mg/yr)	Blasting_CO (mg/yr)
Lafarge PL 1	1914596.784		18380129126	7084008101	306335485.4
Lafarge PL1-scenario1	1914596.784		18380129126	7084008101	306335485.4

Figure 7-11: Raw Material Extraction Emissions (blasting)

Process_Line	Clinker (t)	Cement (t)	Amount of LimeStone	Cao (t)	Mgo (t)	Fuel FOR LimeStone Transport(t)	Clay (t/yr)			
Lafarge PL 1		1659096	1747028.088	1914596.784	1078412.4	33181.92	0	820917.383		
Lafarge PL1-scenario1		1659096	1747028.088	1914596.784	1078412.4	33181.92	0	820917.383		
Process_Line	Non Carbonate Raw Material (t)	Non Carbonate CaO (t)	Non Carbonate MgO (t)	Fuel for fuel transport(t)	Fuel for stationary combustion (t/yr)	CKD (t)	CKD_Recycle	CKD_LandFill	CKD_Sold (t)	
Lafarge PL 1	0	0	0	322.983092	153153.8503		54710.28333	136775708	54710283.3	82065425
Lafarge PL1-scenario1	0	0	0	673.094919	478757.624		54710.28333	136775708	0	0

Figure 7-12: Resource Amounts Used

7.6. Demonstrative Application: Lafarge Industry

This part of the chapter aims at demonstrating some of the CREMA model outputs and possible useful manipulations. Inputs entered by the users are identified and resulting outputs are shown. Using the outputs, an evaluation is carried out using comparative analysis.

Below are the inputs used in the model (Obtained from the Lafarge website)

Table 7-1: Lafarge Cement Production Line Inputs

Process Information		
Annual Capacity of Facility	10,600,000	tones of Cement
Annual Clinker Capacity	8,295,478	tones of Clinker
Number of Production Lines	5	
Number of Process Kilns	5	
Amount of Clinker per kiln	1,659,096	tones/year (assumed to be identical in all kilns)
Dust Filtration System	ESP	
Kiln Fuel	Natural Gas and Heavy Fuel Oil	
Raw Materials	Limestone and clays	
Limestone quarry	Plant area	
Method of Excavation of Limestone	Drilling and blasting	
Clays	25 km from plant area	
Transport Method	Heavy Fuel Oil operated Trucks	
Raw Mix	Limestone 70%, clays 30% (predominantly calcium carbonate, aluminum oxide, silica and iron oxide)	
Portland Cement Clinker	65-79	%
Limestone	6 – 20	%
Minor additional Constituents	0-5	%

7.7. Results and Analysis Drawn

To reduce its CO₂ emissions, a cement company can undertake one of three industrial ecology strategies:

Fuel Substitution

As alternative raw materials, they decrease the amount of non-renewable raw materials needed to produce cement and reduce CO₂ emissions linked to the cement manufacturing process.

- Fuel substitution of conventional fuels and the use of biomass and waste instead. According to the outputs from the CREMA model, 36.5%, 28.2%, and 47.1 % of the total CO₂ emissions are the result of stationary combustion when fuel oil, natural gas and coke are burned as fuels respectively. Replacing these fuels with carbon neutral fuels such as agricultural residues, will therefore result in a drop of 28.2% to 47.1 % of the total CO₂ emissions.
- An avoided NO_x emissions of 15-20 % that would have been released if conventional fuels are used in the kilns and an avoided 6126 kg of NO_x if rice straw is burned in the fields.
- A 29-39 % reduction in SO_x emissions that would have been emitted if conventional fuels are used in the kilns. This is an amount of 3,000,000-5,000,000 kg of Sox emissions in addition to 143,627 kg of SO_x emissions as a result of rice straw open burning.
- An avoided annual emission of 19,411- 75, 151 kg of CH₄ when replaced by agricultural residues that is carbon neutral.
- An avoided 28,198,824 kg of CO that would have occurred as a result of field burning of rice straw

Alternative Raw Materials

- Since raw materials are used as a substitute for clinker, they reduce the amount of clinker used to produce cement and also the fuel required to produce the clinker.

A 50 % decrease in clinker, resulted in a 50 % decrease in the amount of required fuel and a 50% decrease in the amount of energy required for clinker production, assuming a linear relationship between energy requirement and amount of clinker.

Reduction in clinker cement ratio by using waste from other industries as cement additives, or alternative raw materials. Reducing the amount of clinker by 50% resulted in about 31.7 % CO₂ reduction and a 50 % decrease in other emissions

CHAPTER 8 : CONCLUSIONS AND FUTURE WORK

CHAPTER 8

CONCLUSIONS, SUMMARY AND FUTURE WORK

Resources are the backbone of all economies. Both resources and environmental wellbeing are necessary for the continuity of life. Without resources, generations cannot meet their needs and without a healthy, pollution free environment, life would be impossible. Since both resources and a healthy environment are inseparable qualities of life, it is established that maintaining both is sufficient to meet the requirements of the three pillars of sustainability, including economy and society.

To set the scene for this work, and to justify choice of topics, it was established that resources sustainability along with environmental responsibility are sufficient for achieving all other dimensions.

Discussed efforts in resource and environmental sustainability research was covered in three levels comprising the following:

1. A resource sustainability roadmap was developed reflecting on the necessary phases required to achieve resource and environmental sustainability. The roadmap components include binding regulations, internal and external issues and needs and expectations of interested Parties, a Strategic Sustainability Management System (using C2C techniques), an implementation phase and a performance analysis. To reach the beyond sustainability stage, the roadmap passes through three stages. The first stage is the compliance stage and it occurs when binding regulations are set obliging all business owners to adhere with set criteria. The second stage is a risk management stage where business owners realize the need to mitigate rather than fix impacts in order to avoid the risks of penalty and the high cost of remediation. Both the first and second stages are

reactive measures to regulations. The last stage is the proactive stage, when business owners realize benefit in implementing resource and environmental sustainability, and decide to make business out of world class sustainable practices.

2. Management level, which was covered in the sustainability management system.

In this part of the work the following was achieved:

- a. A Comparison was made between different, already existing management systems, concluding possible loopholes and results for failures in the systems.
- b. A sustainability management system (SMS) was developed as a major component of the roadmap established. Reasons for suggesting a new management system rather than the worldwide known ISO 14001 were:
 - ISO 14001 is not enough of a driver to lead to its main cause, environmental protection.
 - It only addresses and evaluates environmental issues.
 - Most implementers do only “Do what is necessary to obtain registration, leading to compliance with the overarching requirements for certification, but failure to conform to the standard requirements in daily operations.
 - Does not have any specific environmental ambitions, environmental end achievements requirements (requirements for the prevention and reduction of the impact of pollution, for instance) without which no certificate is rewarded.
 - Does not indicate environmental performance improvement benchmark requirements.

The sustainability management system on the other hand:

Is located as part of a whole system of transformation, i.e. is a main component of the sustainability roadmap developed. That being the situation leads to:

- Unlike EMS, regulations, External and internal issues and stakeholders needs are the main driver for compliance in the primary stages and beyond compliance in the proactive roadmap stage.
- Addresses all dimensions of sustainability, using cradle- to- cradle evaluation techniques. This ensures that resource sustainability and environmental sustainability is conformed to and thus the social and economic dimensions are automatically taken care of. This unlike conventional EMS means an integrated approach.
- Registration is bonded by regulations which dictate implementers in a certain integrated cradle-cradle approach so meeting " just what is needed for registration" still puts businesses in the right direction. This later becomes a self generating continuous process led by business motivation rather than compliance.
- Fixes goals, targets and benchmarks to be achieved as a result of the possible attainment of which a certificate would be obtained
- Indicates resource and environmental performance improvement benchmark requirements.

3. Quantitative level which was covered by The Cement Resource and Emissions Monitoring Application (CREMA) which is an application on the cement

industry. This tool is the quantitative part of the roadmap which evaluates processes based on three broad categories, namely:

- Emissions from different parts of the cement processes starting from the acquisition of raw materials to the exit of waste and products from the factory gate.
- Amounts of resources used, comprising fuels, limestone, clay, additives and cement kiln dust which is also considered a resource.
- Amount of energy used for both stationary and mobile combustion.

Results from this sub model is fed to the model to calculate emissions and amounts of resources. In other words,

- the less the energy requirement, the less the amount of resources needed in the processes.
- The greater the calorific value of the fuel, the less the amount needed.
- The higher the efficiency of the process, the less the amount of fuel needed.

The model has two parts to it:

- Baseline scenario part, which calculates impacts based on business as usual
- Alternative scenario part, which allows the user to copy the baseline scenario and vary parameters to examine impacts compared to the baseline scenario. This part mainly focuses on alternative fuels from agricultural waste and municipal solid waste.

The model therefore allows the user to :

- Determine baselines at the outset of the roadmap for policy setting within the SMS
- Determine, optimize and compare possible alternative scenarios in terms of resources, energy requirement, emissions, avoided emissions.

REFERENCES

- Allen, C. V. (1992). The new business imperatives in the environmental regulation area - impact of environmental concerns on business transactions: Who really pays? *Canada-United States Law Journal*, 18, 351.
- Ambec, S., & Ehlers, L. (2014). Regulation via the polluter-pays principle. *The Economic Journal*, , n/a. doi:10.1111/eoj.12184
- Askar, Y., Jago, P., Mourad, M., & Huisin, D. (2012). The cement industry in Egypt: Challenges and innovative Cleaner Production solutions. Paper presented at Knowledge Collaboration & Learning for Sustainable Innovation ERSCP-EMSU conference, Delft, The Netherlands, file:///C:/Users/GIG/Downloads/379_Askar.pdf
- Baumann, H., & Tillman, A. (2004). *The hitch hiker's guide to LCA: An orientation in life cycle assessment methodology and application*. Lund, Sweden: Studentlitteratur.
- Bidstrup, M. (2015). Life cycle thinking in impact assessment—Current practice and LCA gains. *Environmental Impact Assessment Review*, 54, 72-79. doi:10.1016/j.eiar.2015.05.003
- Braungart, M., & McDonough, W. (2012). Cradle to Cradle CertifiedCM Product Standard.
- BS OHSAS 18001:2007: *Occupational health and safety management systems – Requirements*. British Standards Institute. London: BSI Global.
- BSDglobal. (2009). *Iisd.org*. Retrieved 15 April, 2016, from https://www.iisd.org/business/sd_journey.aspx
- C2C product certification overview - get certified - cradle to cradle products innovation institute. (2014). Retrieved April 10, 2016, from <http://www.c2ccertified.org/get-certified/product-certification>
- Chai, N. (2009;2014;). *Sustainability performance evaluation system in government: A balanced scorecard approach towards sustainable development* (1st ed.). Dordrecht: Springer Verlag. doi:10.1007/978-90-481-3012-2
- Chapter from C. Clini, I. Musu, M. Gullino, eds., *Sustainable Development and Environmental Management*, Springer, 2008
- Chertow, M. R. (2007). “Uncovering” industrial symbiosis. *Journal of Industrial Ecology*, 11(1), 11-30. doi:10.1162/jiec.2007.1110

Ciravegna Martins da Fonseca, Luis Miguel. (2015). ISO 14001:2015: An improved tool for sustainability. *Journal of Industrial Engineering and Management*, 8(1), 37-50. doi:10.3926/jiem.1298

Clini, C., Musu, I., Gullino, M. L., & ebrary, I. (2008). *Sustainable development and environmental management: Experiences and case studies*. Dordrecht: Springer.

CO2 EMISSIONS FROM CEMENT PRODUCTION Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories
http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/3_1_Cement_Production.pdf

Corbett, Charles J., Russo, Michael V. (2001) ISO 14001: irrelevant or invaluable? Special Report. *ISO Management Systems*. www.iso.org/ims

Dechezleprêtre, A., Sato, M. (2014). The impacts of environmental regulations on competitiveness. Policy Brief, Grantham Research Institute on Climate Change and the Environment, LSE

Drexhage, J., & Murphy, D. (2010). Sustainable development: From Brundtland to Rio 2012 United Nations Headquarters, New York.

Dumoulin, F., & Wassenaar, T. (2014). Environment in industrial ecology, grasping a complex notion for enhancing industrial synergies at territorial scales. *Sustainability*, 6(9), 6267-6277. doi:10.3390/su6096267

EC (2015) Sustainable use of natural resources. Retrieved from <http://ec.europa.eu/environment/natres/>

El -Haggar, S. M (2007). Sustainable industrial design and waste management. El-Sevier Academic Press.

El -Haggar, S. M. (2015). *Sustainability and innovation: The next global industrial revolution*. Cairo, New York: The American University In Cairo Press.

Environmental audit committee. (2010, April 28). Retrieved April 9, 2016, from <http://www.parliament.uk/business/committees/committees-a-z/commons-select/environmental-audit-committee/>

Fernández-Muñiz, B., Montes-Peón, J. M., & Vázquez-Ordás, C. J. (2012). Occupational risk management under the OHSAS 18001 standard: Analysis of perceptions and attitudes of certified firms. *Journal of Cleaner Production*, 24, 36-47. doi:10.1016/j.jclepro.2011.11.008

Getting to Green. A Sourcebook of Pollution Management Policy Tools for Growth and Competitiveness. (2012). The International Bank for Reconstruction and Development, THE WORLD BANK.

http://siteresources.worldbank.org/ENVIRONMENT/Resources/Getting_to_Green_web.pdf

Gillenwater, Michael. (2005) *Calculation Tool for Direct Emissions from Stationary Combustion, version 3.0, WRI/ WBCSD GHG Protocol*. Retrieved from http://www.ghgprotocol.org/files/ghgp/tools/Stationary_Combustion_Guidance_final.pdf

Governance and management. (n.d.). Retrieved August 10, 2016, from http://www.kumba-online.co.za/reports/kumba_ar2010/responsibility/ovr_ov_gov.php

Heinberg, R (2007) *Peak everything—waking up to the century of declines*. New Society Publishers, Gabriola Island

Heras-Saizarbitoria, I., & Boiral, O. (2013). ISO 9001 and ISO 14001: Towards a research agenda on management system standards. *International Journal of Management Reviews*, 15(1), 47-65. doi:10.1111/j.1468-2370.2012.00334.x

Hitchcock, D. E., & Willard, M. L. (2006). *The business guide to sustainability: Practical strategies and tools for organizations*. Sterling, VA;London,: Earthscan.

Hopwood, B., Mellor, M., & O'Brien, G. (2005). Sustainable development: Mapping different approaches. *Sustainable Development*, 13(1), 38-52. doi:10.1002/sd.244

Initiative, C. S. (2005). The Cement CO2 Protocol: CO2 Accounting and Reporting Standard for the Cement Industry, guidance document. Retrieved from http://www.ghgprotocol.org/files/ghgp/tools/co2_CSI_Cement_Protocol-V2.0.pdf

IPCC (2000). Industrial Processes. In. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Prepared by the Intergovernmental Panel on Climate Change (IPCC). Retrieved from http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/3_1_Cement_Production.pdf

IPCC (2006). 2006 Stationary Combustion. In IPCC Guidelines for National Greenhouse Gas Inventories Vol. 2, Ch. 2, Prepared by the National Greenhouse Gas Inventories Programme. Published: IGES, Japan.

ISO 14040:2006. *Environmental management- life cycle assessment- principles and framework*, International Organization for Standardization, Geneva.

ISO 14001:2015. *Environmental management systems — Requirements with guidance for use*, International Organization for Standardization, Geneva.

ISO. (2015). ISO 14000 - Environmental management. Retrieved from <http://www.iso.org/>: <http://www.iso.org/iso/home/standards/management-standards/iso14000.htm>

James, S. (2004). *Natural step for communities : How cities and towns can change to sustainable practices* New Society Publishers.

Justicegcca. (2016). *Justicegcca*. Retrieved 9 April, 2016, from <http://laws-lois.justice.gc.ca/eng/acts/F-8.6/FullText.html>

Lombardi, D. R., Lyons, D., Shi, H., & Agarwal, A. (2012). Industrial symbiosis. *Journal of Industrial Ecology*, 16(1), 2-7. doi:10.1111/j.1530-9290.2012.00455.x

MBDC, LLC (2012). Cradle to Cradle Certified Product Standard. Retrieved from http://www.c2ccertified.org/images/uploads/C2CCertified_Product_Standard_V3_121112.pdf

McDonough W and Braungart M (2013) *The Upcycle: Beyond Sustainability – Designing for Abundance*. New York, USA: North Point Press.

Mineralsuk. Retrieved from <http://www.bgs.ac.uk/mineralsuk/statistics/risklist.html>

Nawrocka, D., Brorson, T., Lindhqvist, T., Internationella miljöinstitutet, Special activities (research centres, institutes etc.), Faculty of Social Sciences. . Särskilda verksamheter (institut, centrubildningar etc.). (2009). ISO 14001 in environmental supply chain practices. *Journal of Cleaner Production*, 17(16), 1435-1443. doi:10.1016/j.jclepro.2009.05.004

Neumayer, Eric & Perkins, Richard. (2004). What explains the uneven take-up of ISO 14001 at the global level? A panel data analysis. *Environment and Planning A*, pp. 823–839.

Olson, D. L., & Dash Wu, D. (2010). A review of enterprise risk management in supply chain. *Kybernetes*, 39(5), 694-706. doi:10.1108/03684921011043198

Pearce D, Markandya A, Barbier E. (1989). *Blueprint for a Green Economy*. Earthscan: London.

Peralta Álvarez, M. E., Aguayo González, F., Lama Ruíz, J. R., & Ávila Gutiérrez, M. J. (2015). MGE2: A framework for cradle-to-cradle design. *Dyna*, 82(191), 137-146. doi:10.15446/dyna.v82n191.43263

Perdan, S., & Azapagic, A. (2010). Measuring sustainable development: An overview. *Sustainable development in practice* (pp. 26-55) John Wiley & Sons, Ltd. doi:10.1002/9780470972847.ch2

“Processes & UN System” . Sustainable Development Knowledge Platform. (n.d.). Retrieved April, from <http://sustainabledevelopment.un.org/intgovmental.html>

Registrar, P. R. (2015). Environmental - ISO 14001. Retrieved from <http://www.prieregistrar.org/>: <http://www.prieregistrar.org/ISO14001-OHSAS-18001/index.html>

Rio Declaration on Environment and Development. (n.d.). Retrieved August 09, 2016, from <http://www.unep.org/documents.multilingual/default.asp?documentid=78>

S.Morris, A. (2004). ISO 14000 Environmental Management Standards. John Wiley & Sons, Ltd.

Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. *Journal of Cleaner Production*, 16(15), 1699-1710. doi:10.1016/j.jclepro.2008.04.020Sourcebook of Pollution Management Policy

Steer, A. (2013). Resource depletion, climate change and economic growth. Global Citizen Foundation (Working Paper 5). Retrieved December 4, 2014, from http://www.gcf.ch/wp-content/uploads/2013/06/GCF_Steer-working-paper-5_6.20.13.pdf

The chartered quality institute, 2nd floor north, chancery exchange, 10 furnival street, london, ec4a 1ab. (2016). *Thecqi.org*. Retrieved 16 April, 2016, from <http://www.thecqi.org>

The cradle-to-cradle alternative. (2003). Retrieved April 9, 2016, from <http://www.mcdonough.com/speaking-writing/the-cradle-to-cradle-alternative/>

The International Organization for Standardization (ISO). (2016). Retrieved 16 April, 2016, from <http://www.iso.org/>

The Natural Step. (n.d.). Retrieved August 09, 2016, from <http://www.thenaturalstep.org/>

Trozzi, C. & Kuenen, Jeroen (2013). Energy Industries. In *EMEP/EEA Guidebook Version 2013*. European Environment Agency, Copenhagen. Retrieved 16 April, 2016, from <http://www.eea.europa.eu/publications/emep-eea-guidebook-2013>

Trozzi, C. (2013). Municipal waste incineration. In *EMEP/EEA Guidebook Version 2013*, EEA Technical report No 12/2013 . European Environment Agency, Copenhagen. Retrieved 16 April, 2016, from <http://www.eea.europa.eu/publications/emep-eea-guidebook-2013>

UNEP (2011) Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A., Sewerin, S.

UNEP (2012) Sustainable Resource Efficient Cities- Making it happen. Retrieved from http://www.unep.org/urban_environment/PDFs/SustainableResourceEfficientCities.pdf

Urama, Kevin, Ozor, Nicholas and Acheampong, Ernest. (2014). *Achieving Sustainable Development Goals (SDGs) Through Transformative Governance Practices and Vertical Alignment at the National and Subnational Levels in Africa*. A synopsis of discussions held at the SDplanNet-Africa. Retrieved from https://www.iisd.org/sites/default/files/publications/sdplanet_africa.pdf

Urbinato, D. (1994). London's historic "pea-soupers". *EPA Journal*. (2012) "OECD environmental outlook to 2050: the consequences of inaction", *International Journal of Sustainability in Higher Education*, Vol. 13 Iss: 3

USEPA. (1995). *Compilation of Air Pollutant Emission Factors for AP-42 Section 11.6. Portland Cement Manufacturing, Final Report*. US EPA, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. Retrieved from. <https://www3.epa.gov/ttnchie1/ap42/ch11/final/c11s06.pdf>

USEPA (1996). *Compilation of Air Pollutant Emission Factors for AP-42 Section 2.1. Refuse Combustion , Final Report*. US EPA, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. Retrieved from. <https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf>

USEPA (2003). *Compilation of Air Pollutant Emission Factors for AP-42 Section 1.6. Wood Residue Combustion In Boilers, Final Report*. US EPA, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. Retrieved from. <https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s06.pdf>

Yin, H., dan Schmeidler, P.J., 2007. Does ISO 14001 Certification Enhance Environmental Performance? Conditions under which Environmental Performance Improvement Occurs. Wharton Risk Center Working Paper # 07-07. Risk Management and Decision Processes Center The Wharton School University of Pennsylvania, Philadelphia.

Zaki, T., Kafafi, A. G., Mina, M. B., & AbdEl-Halim, M. (2013). Annual report for solid waste management in egypt. (No. Annual Report Volume 2). Cairo: Ministry of State for Environmental Affairs.

APPENDIX A: 14001:2015



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Introduction

This draft standard is based on international discussions in which the UK has taken an active part. Your comments on this draft are invited and will assist in the preparation of the consequent standard. Comments submitted will be reviewed by the relevant BSI committee before sending the consensus UK vote and comments to the international secretariat, which will then decide appropriate action on the draft and the comments received.

If the international standard is approved, it is possible the text will be published as an identical British Standard.

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Please indicate whether you consider the UK should submit a negative (with reasons) or positive vote on this draft.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	(7)
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/ Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

DRAFT INTERNATIONAL STANDARD

ISO/DIS 14001

ISO/TC 207/SC 1

Secretariat: **BSI**

Voting begins on:
2014-08-28

Voting terminates on:
2014-11-28

Environmental management systems — Requirements with guidance for use

Systèmes de management environnemental — Exigences et lignes directrices pour son utilisation

ICS: 13.020.10

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ISO/CEN PARALLEL PROCESSING

This draft has been developed within the International Organization for Standardization (ISO), and processed under the **ISO lead** mode of collaboration as defined in the Vienna Agreement.

This draft is hereby submitted to the ISO member bodies and to the CEN member bodies for a parallel five month enquiry.

Should this draft be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month approval vote in ISO and formal vote in CEN.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: [Foreword - Supplementary information](#). The committee responsible for this document is Technical Committee ISO/TC 207, *Environmental management*, Subcommittee SC 1, *Environmental management systems*.

This third edition will cancel and replace the second edition (ISO 14001:2004), which has been technically revised.

NOTE TO THIS TEXT (which will not be included in the published International Standard):

This text has been prepared using the a high level structure, identical core text, and common terms with core definitions, designed to benefit users implementing multiple ISO management system standards, as set out in Annex SL, Appendix 2 of the ISO/IEC Directives, Part 1, Consolidated ISO Supplement, 2014.

The text of Annex SL is shown in the main body of the text (Clauses 1 to 10) by the use of black font. All other text is shown in blue font. This is only to facilitate analysis and will not be incorporated in the final version of ISO 14001.

2 0 Introduction

3 0.1 Background

4 Achieving a balance between environmental, social and economic sub-systems within the global system is
5 considered essential in order to meet the needs of the present without compromising the ability of future
6 generations to meet their needs. This concept of the 'three pillars' of sustainability is the goal of sustainable
7 development.

8 Societal expectations for sustainable development, transparency and accountability have evolved within the
9 context of increasingly stringent legislation, growing pressures on the environment from pollution, and the
10 inefficient use of resources, management of waste, climate change and degradation of eco-systems and
11 biodiversity.

12 This has led organizations to adopt a systematic approach to environmental management by implementing
13 environmental management systems with the aim to contribute to the 'environmental pillar' of sustainability.

14 0.2 Aim of an environmental management system

15 The purpose of this International Standard is to provide organizations with a systematic framework to protect
16 the environment and respond to changing environmental conditions in balance with socio-economic needs. It
17 does so by specifying requirements for an environmental management system that enables an organization to
18 enhance environmental performance by:

- 19 — developing and implementing an environmental policy and objectives;
- 20 — identifying aspects of its activities, products and services that can result in significant environmental
21 impacts;
- 22 — establishing systematic processes which consider its context, and take into account its significant
23 environmental aspects, risk associated with threats and opportunities and its compliance obligations;
- 24 — increasing awareness of its relationship with the environment;
- 25 — establishing operational controls to manage its significant environmental aspects and compliance
26 obligations;
- 27 — evaluating environmental performance and taking actions, as necessary.

28 A systematic approach to environmental management can provide top management with information to build
29 success over the long term and create options for contributing to sustainable development by:

- 30 — protecting the environment by preventing or reducing adverse impacts on the environment;
- 31 — mitigating the potential adverse impact of environmental conditions on the organization;
- 32 — assisting in conforming to compliance obligations;
- 33 — enhancing environmental performance;
- 34 — controlling or influencing the way the organization's products and services are designed, manufactured,
35 distributed, consumed and disposed by using a life cycle perspective that can prevent environmental
36 burdens from being inadvertently shifted elsewhere within the cycle;
- 37 — achieving financial and operational benefits that can result from implementing environmentally sound
38 alternatives that strengthen the organization's market position;

39 — communicating environmental information to relevant interested parties.

40 **0.3 Success factors**

41 The success of an environmental management system depends on commitment from all levels and functions
42 of the organization, led by top management. They can leverage opportunities to reduce or eliminate
43 environmental impacts, particularly those with strategic and competitive implications. Top management can
44 effectively address these opportunities by integrating environmental management into its business processes,
45 strategy and decision making, aligning them with other business priorities, and incorporating environmental
46 governance into its overall management system. Demonstration of successful implementation of this
47 International Standard can be used to assure interested parties that an appropriate environmental
48 management system is in place.

49 Adoption of this International Standard, however, will not in itself guarantee optimal environmental outcomes.
50 Two organizations can carry out similar activities but may have different compliance obligations,
51 environmental policy commitments, environmental technologies in use and environmental performance goals,
52 yet both can conform to the requirements of this International Standard.

53 The level of detail and complexity, the extent of documentation and the resources needed for an
54 environmental management system will depend on a number of factors, such as the organization's context, its
55 size and location, its compliance obligations, the scope of the system, and the nature of its activities, products
56 and services, including its environmental aspects and potential impacts.

57 **0.4 Plan, Do, Check and Act approach**

58 The basis for the approach underlying an environmental management system is founded on the Shewhart
59 concept of Plan, Do, Check and Act (PDCA) made popular by Deming. The PDCA model demonstrates an
60 iterative process used by organizations to achieve continual improvement. It can be applied to a management
61 system and to each of its individual elements. It can be briefly described as follows.

62 — Plan: establish objectives and processes necessary to deliver results in accordance with the
63 organization's policy.

64 — Do: implement the processes as planned.

65 — Check: monitor and measure processes against the policy, including its commitments, objectives and
66 operational controls, and report the results.

67 — Act: take actions to continually improve.

68 This International Standard incorporates the PDCA concept into a new framework, as shown in Figure 1.

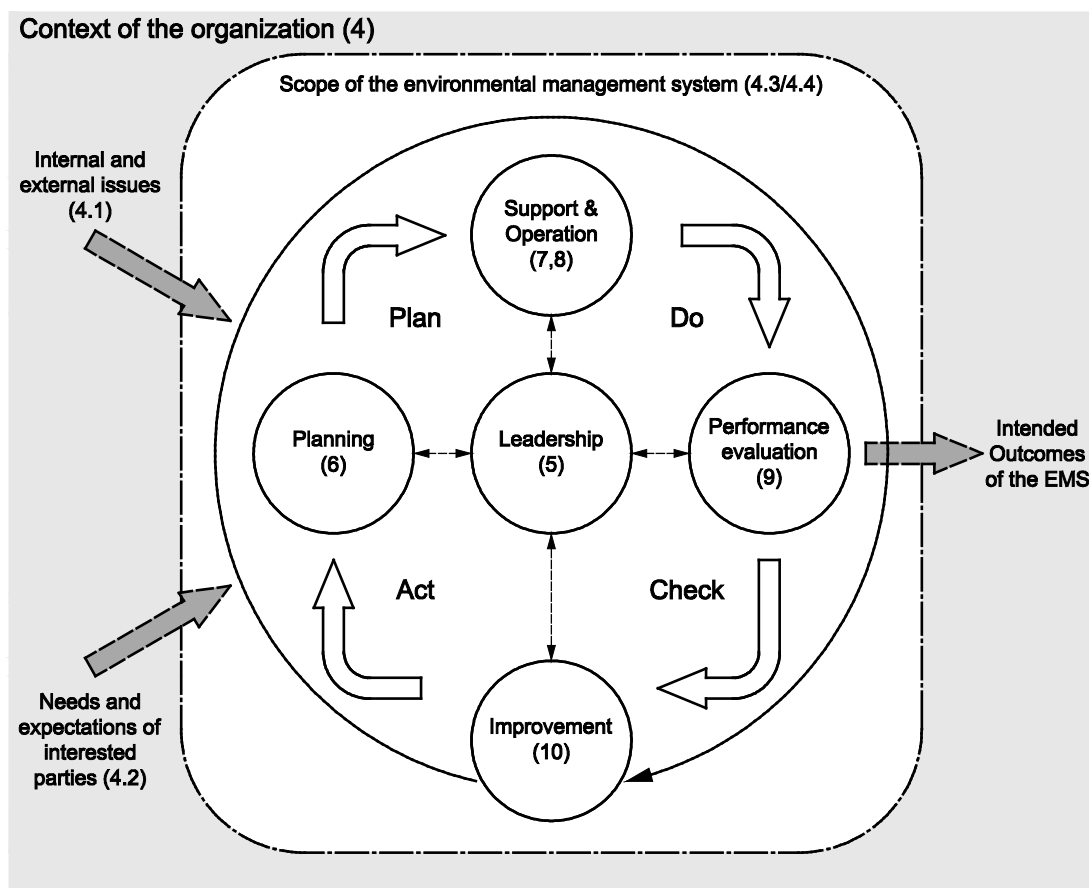


Figure 1 — Environmental management system model for this International Standard

0.5 Contents of this International Standard

This International Standard includes revisions to meet environmental challenges facing organizations and provide value to both new and existing users. It also includes revisions to conform to ISO's requirements for management system standards¹⁾. These requirements include a high level structure, identical core text, and common terms with core definitions, designed to benefit users implementing multiple ISO management system standards.

The body of this International Standard, Clauses 1 through 10, contains the requirements used to assess conformity. Annex A provides informative explanations to prevent misinterpretation of ISO/DIS 14001:2014 requirements. Annex B identifies broad technical correspondence between the previous edition of this International Standard (ISO 14001:2004) and this edition. Implementation guidance on environmental management systems is included in ISO 14004²⁾.

1) See the ISO/IEC Directives, Part 1, Consolidated ISO Supplement, Procedures specific to ISO, Fifth edition, 2014, Annex SL, Appendices 2 and 3.

2) Revision of ISO 14004 is ongoing.

Environmental management systems — Requirements with guidance for use

1 Scope

This International Standard specifies the requirements of an environmental management system for organizations seeking to establish, implement, maintain and continually improve a framework with the aim to manage its environmental responsibilities in a manner that contributes to the 'environmental pillar' of sustainability.

The intended outcomes of an environmental management system provide value for the environment, the organization and its interested parties. Consistent with the organization's environmental policy, the intended outcomes of an environmental management system include:

- enhancement of environmental performance;

- conforming to compliance obligations;

- fulfilment of environmental objectives.

This International Standard is applicable to any organization regardless of size, type and nature and applies to the environmental aspects that the organization determines it can either control or can influence considering a life cycle perspective. It does not state specific environmental performance criteria, nor does it increase or change an organization's legal obligations.

This International Standard can be used in whole or in part to improve environmental management, but all the requirements are intended to be incorporated into an environmental management system and fulfilled, without exclusion, if an organization claims it complies with this International Standard.

2 Normative references

No normative references are cited. This clause is included to maintain clause numbering alignment with other ISO management system standards.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

organization

person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its *objectives* (3.16)

Note 1 to entry: The concept of organization includes, but is not limited to sole-trader, company, corporation, firm, enterprise, authority, partnership, charity or institution, or part or combination thereof, whether incorporated or not, public or private.

3.2

top management

person or group of people who directs and controls an *organization* (3.1) at the highest level

Note 1 to entry: Top management has the power to delegate authority and provide resources within the organization.

Note 2 to entry: If the scope of the *management system* (3.3) covers only part of an organization, then top management refers to those who direct and control that part of the organization.

3.3

management system

set of interrelated or interacting elements of an *organization* (3.1) to establish policies and *objectives* (3.16) and *processes* (3.26) to achieve those objectives

Note 1 to entry: A management system can address a single discipline or several disciplines (e.g. *quality*, *environment*, *occupational health and safety*).

Note 2 to entry: The system elements include the organization's structure, roles and responsibilities, planning and operation, *performance evaluation and improvement*.

Note 3 to entry: The scope of a management system may include the whole of the organization, specific and identified functions of the organization, specific and identified sections of the organization, or one or more functions across a group of organizations.

3.4

environmental management system

part of the *management system* (3.3) used to manage *environmental aspects* (3.9), conform to *compliance obligations* (3.22), and address *risk* (3.18) associated with threats and opportunities

3.5

interested party

person or *organization* (3.1) that can affect, be affected by, or perceive itself to be affected by a decision or activity

Note 1 to entry: Interested parties can include person(s) and groups concerned with or affected by the *environmental performance* (3.13) of an organization.

Note 2 to entry: To "perceive itself to be affected" means the perception has been made known to the organization.

Note 3 to entry: Interested parties can include customers, communities, suppliers, regulators, nongovernment organizations, investors, employees.

3.6

environmental policy

intentions and direction of an *organization* (3.1) as formally expressed by its *top management* (3.2) *related to environmental performance* (3.13)

3.7

documented information

information required to be controlled and maintained by an *organization* (3.1) and the medium on which it is contained

Note 1 to entry: Documented information can be in any format and media, and from any source.

Note 2 to entry: Documented information can refer to:

- the *environmental management system* (3.4), including related *processes* (3.26);
- information created in order for the organization to operate (*may also be referred to as documentation*);

156 — evidence of results achieved (may also be referred to as records).

157 3.8

158 environment

159 surroundings in which an *organization* (3.1) operates including air, water, land, natural resources, flora, fauna,
160 humans and their interrelations

161 Note 1 to entry: Surroundings in this context can extend from within an organization to the local, regional and global
162 system.

163 Note 2 to entry: Surroundings may be described in terms of biodiversity, ecosystems, climate or other characteristics.

164 3.9

165 environmental aspect

166 element of an *organization's* (3.1) activities or products or services that interacts or can interact with the
167 *environment* (3.8)

168 Note 1 to entry: An environmental aspect can cause (an) *environmental impact(s)* (3.10). A significant environmental
169 aspect is one that has or can have a significant environmental impact.

170 Note 2 to entry: Significant environmental aspects are determined by the organization applying one or more criteria.

171 3.10

172 environmental impact

173 change to the *environment* (3.8), whether adverse or beneficial, wholly or partially resulting from an
174 *organization's* (3.1) *environmental aspects* (3.9)

175 3.11

176 environmental condition

177 state or characteristic of the *environment* (3.8) as determined at a certain point of time

178 3.12

179 performance

180 measurable result

181 Note 1 to entry: Performance can relate either to quantitative or qualitative findings.

182 Note 2 to entry: Performance can relate to the management of activities, *processes* (3.26), products (including
183 services), systems or *organizations* (3.1).

184 3.13

185 environmental performance

186 *performance* (3.12) related to the management of *environmental aspects* (3.9)

187 Note 1 to entry: In the context of *environmental management systems* (3.4), results can be measured against the
188 organization's *environmental policy* (3.6), *environmental objectives* (3.17) or other criterion, using indicators.

189 3.14

190 prevention of pollution

191 use of *processes* (3.26), practices, techniques, materials, products, services or energy to avoid, reduce or
192 control (separately or in combination) the creation, emission or discharge of any type of pollutant or waste, in
193 order to reduce adverse *environmental impacts* (3.10)

194 Note 1 to entry: Prevention of pollution can include source reduction or elimination, process, product or service
195 changes, efficient use of resources, material and energy substitution, reuse, recovery, recycling, reclamation and
196 treatment.

3.15

life cycle

consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to end-of-life treatment

Note 1 to entry: Life cycle includes activities, products, and services and may include procured goods and services, as well as end-of-life treatment of products and delivery of services, for example, design, manufacture, transport, packaging and end-use or disposal.

[Source: ISO 14044:2006, 3.1, modified — refer to 'end-of-life treatment', not 'final disposal', Note 1 to entry was added].

3.16

objective

result to be achieved

Note 1 to entry: An objective can be strategic, tactical, or operational.

Note 2 to entry: Objectives can relate to different disciplines (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product, service and *process* (3.26)).

Note 3 to entry: An objective can be expressed in other ways, e.g. as an intended outcome, a purpose, an operational criterion, as an *environmental objective* (3.17), or by the use of other words with similar meaning (e.g. aim, goal, or target).

3.17

environmental objective

objective (3.16) set by the *organization* (3.1) consistent with the *environmental policy* (3.6)

3.18

risk

effect of uncertainty on *objectives* (3.16)

Note 1 to entry: An effect is a deviation from the expected — positive or negative.

Note 2 to entry: Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of, an event, its consequence, or likelihood.

Note 3 to entry: Risk is often characterized by reference to potential “*events*” (as defined in ISO Guide 73:2009, 3.5.1.3) and “*consequences*” (as defined in ISO Guide 73:2009, 3.6.1.3), or a combination of these.

Note 4 to entry: Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated “*likelihood*” (as defined in ISO Guide 73:2009, 3.6.1.1) of occurrence.

3.19

competence

ability to apply knowledge and skills to achieve intended results

3.20

effectiveness

extent to which planned activities are realized and planned results achieved

3.21

requirement

need or expectation that is stated, generally implied or obligatory

Note 1 to entry: “Generally implied” means that it is custom or common practice for the *organization* (3.1) and *interested parties* (3.5) that the need or expectation under consideration is implied.

Note 2 to entry: A specified requirement is one that is stated, for example in *documented information* (3.7).

239 Note 3 to entry: Requirements other than legal requirements become obligatory when the organization decides to
 240 comply with them.

241 3.22

242 compliance obligation

243 *requirement* (3.21) that an *organization* (3.1) has to or chooses to comply with

244 Note 1 to entry: Obligations may arise from mandatory *requirements* (3.21), such as applicable laws and regulations,
 245 or voluntary commitments, such as organizational and industry standards, contractual relationships, principles of good
 246 governance and community and ethical standards.

247 [Source: ISO/DIS 19600:2014, 3.31]

248 3.23

249 conformity

250 fulfilment of a *requirement* (3.21)

251 3.24

252 nonconformity

253 non-fulfilment of a *requirement* (3.21)

254 Note 1 to entry: Nonconformity relates to *compliance obligations* (3.22), including requirements in this International
 255 Standard and additional *environmental management system* (3.4) requirements that an *organization* (3.1) establishes for
 256 itself.

257 3.25

258 corrective action

259 action to eliminate the cause of a *nonconformity* (3.24) and to prevent recurrence

260 3.26

261 process

262 set of interrelated or interacting activities which transforms inputs into outputs

263 Note 1 to entry: Processes can be documented or not.

264 3.27

265 measurement

266 *process* (3.26) to determine a value

267 3.28

268 audit

269 systematic, independent and documented *process* (3.26) for obtaining audit evidence and evaluating it
 270 objectively to determine the extent to which the audit criteria are fulfilled

271 Note 1 to entry: An internal audit is conducted by the *organization* (3.1) itself or by an external party on its behalf.

272 Note 2 to entry: An audit can be a combined audit (combining two or more disciplines).

273 Note 3 to entry: Independence can be demonstrated by the freedom from responsibility for the activity being audited or
 274 freedom from bias and conflict of interest.

275 Note 4 to entry: "Audit evidence" consists of verifiable records, statements of fact and other information relevant to the
 276 audit criteria, and "audit criteria" are the set of policies, *procedures* (3.30) or *requirements* (3.21) used as a reference
 277 against which audit evidence is compared, as defined in ISO 19011.

278 3.29

279 continual improvement

280 recurring activity to enhance *performance* (3.12)

Note 1 to entry: Enhancing performance relates to the use of the *environmental management system* (3.4) in order to enhance *environmental performance* (3.13) consistent with the *organization's* (3.1) *environmental policy* (3.6).

Note 2 to entry: The activity need not take place in all areas simultaneously, or without interruption.

3.30
procedure
specified way to carry out an activity or a *process* (3.26)

Note 1 to entry: Procedures can be documented or not.

3.31
monitoring
determining the status of a system, a *process* (3.26) or an activity

Note 1 to entry: To determine the status, there may be a need to check, supervise or critically observe.

3.32
outsource (verb)
make an arrangement where an external *organization* (3.1) performs part of an organization's function or *process* (3.26)

Note 1 to entry: An external organization is outside the scope of the *management system* (3.3), although the outsourced function or process is within the scope.

3.33
indicator
measurable representation of the condition or status of operations, management or conditions

[SOURCE: ISO 14031:2013, 3.15]

4 Context of the organization

4.1 Understanding the organization and its context

The organization shall determine external and internal issues that are relevant to its purpose and that affect its ability to achieve the intended outcome(s) of its environmental management system. Those issues include environmental conditions capable of affecting or being affected by the organization.

4.2 Understanding the needs and expectations of interested parties

The organization shall determine:

- the interested parties that are relevant to the environmental management system;
- the relevant needs and expectations (i.e. requirements) of these interested parties;
- which of these needs and expectations become compliance obligations.

4.3 Determining the scope of the environmental management system

The organization shall determine the boundaries and applicability of the environmental management system to establish its scope.

When determining this scope, the organization shall consider:

- the external and internal issues referred to in 4.1;

317 — the **compliance obligations** referred to in 4.2;

318 — its organizational unit(s), function(s), and physical boundaries;

319 — its activities, products and services;

320 — its authority and ability to exercise control and influence.

321 Once the scope is defined, activities, products and services that can have significant environmental aspects
322 (see 6.1.2) shall be included within the scope of the environmental management system.

323 The scope shall be **maintained** as documented information **and be** available **to interested parties**.

324 **4.4 Environmental management system**

325 The organization shall establish, implement, maintain and continually improve an environmental management
326 system, including the processes needed and their interactions, in accordance with the requirements of this
327 International Standard, **to enhance its environmental performance**.

328 The organization shall consider the knowledge of its context when establishing and maintaining the
329 environmental management system.

330 **5 Leadership**

331 **5.1 Leadership and commitment**

332 Top management shall demonstrate leadership and commitment with respect to the environmental
333 management system by:

334 — **taking accountability for the effectiveness of the environmental management system;**

335 — ensuring that the environmental policy and environmental objectives are established and are compatible
336 with the strategic direction **and the context** of the organization;

337 — ensuring the integration of the environmental management system requirements into the organization's
338 business processes;

339 — ensuring that the resources needed for the environmental management system are available;

340 — communicating the importance of effective environmental management and of conforming to the
341 environmental management system requirements;

342 — ensuring that the environmental management system achieves its intended outcome(s);

343 — directing and supporting persons to contribute to the effectiveness of the environmental management
344 system;

345 — promoting continual improvement;

346 — supporting other relevant management roles to demonstrate their leadership as it applies to their areas of
347 responsibility.

348 NOTE Reference to "business" in this International Standard can be interpreted broadly to mean those activities that
349 are core to the purposes of the organization's existence.

350 **5.2 Environmental policy**

351 Top management shall establish, implement and maintain an environmental policy that, within the defined
352 scope of its environmental management system:

353 a) is appropriate to

354 1) the purpose of the organization;

355 2) the organization's context, including the nature, scale and environmental impacts of its activities,
356 products and services;

357 b) provides a framework for setting environmental objectives;

358 c) includes (a) commitment(s) to the protection of the environment, including prevention of pollution and
359 others specific to the context of the organization;

360 **NOTE** Other specific commitment(s) to protect the environment can include sustainable resource use, climate change
361 mitigation and adaptation, and protection of biodiversity and ecosystems, or other relevant environmental issues (see 4.1).

362 d) includes a commitment to conform to compliance obligations;

363 e) includes a commitment to continual improvement of the environmental management system to enhance
364 environmental performance.

365 The environmental policy shall:

366 — be maintained as documented information;

367 — be communicated within the organization, including persons doing work under the organization's control;

368 — be available to interested parties.

369 **5.3 Organizational roles, responsibilities and authorities**

370 Top management shall ensure that the responsibilities and authorities for relevant roles are assigned and
371 communicated within the organization to facilitate effective environmental management.

372 Top management shall assign the responsibility and authority for:

373 a) ensuring that the environmental management system conforms to the requirements of this International
374 Standard;

375 b) reporting on the performance of the environmental management system, including environmental
376 performance, to top management.

377 **6 Planning**

378 **6.1 Actions to address risk associated with threats and opportunities**

379 **6.1.1 General**

380 The organization shall plan and implement a process to meet the requirements in 6.1.

381 When planning for the environmental management system in 6.1 (i.e. 6.1.2 - 6.1.4), the organization shall
382 consider the issues referred to in 4.1 and the requirements referred to in 4.2.

383 The organization shall maintain documented information to the extent necessary to have confidence that the
 384 process has been carried out as planned.

385 **6.1.2 Significant environmental aspects**

386 Within the defined scope of the environmental management system, the organization shall:

387 a) identify the environmental aspects and associated environmental impacts of its activities, products and
 388 services that it can control and those that it can influence, considering a life cycle perspective;

389 b) take into account:

390 1) change, including planned or new developments and new or modified activities, products and
 391 services;

392 2) identified abnormal and potential emergency situations.

393 The organization shall determine those aspects that have or can have a significant impact on the environment,
 394 i.e. significant environmental aspects.

395 The organization shall communicate its significant environmental aspects among the various levels and
 396 functions of the organization.

397 The organization shall maintain documented information of its:

398 — criteria used to determine its significant environmental aspects;

399 — environmental aspects and associated environmental impacts;

400 — significant environmental aspects.

401 **NOTE** Significant environmental aspects can result in risk associated with either adverse environmental impacts
 402 (threats) or beneficial environmental impacts (opportunities).

403 **6.1.3 Compliance obligations**

404 The organization shall:

405 a) identify and have access to the compliance obligations related to its environmental aspects;

406 b) determine how these compliance obligations apply to the organization.

407 The organization shall maintain documented information of its compliance obligations.

408 **NOTE** Compliance obligations can have the potential to result in risk associated with either adverse impacts (threats)
 409 or beneficial impacts (opportunities) to the organization.

410 **6.1.4 Risk associated with threats and opportunities**

411 The organization shall determine the risk associated with threats and opportunities that needs to be
 412 addressed to:

413 — give assurance that the environmental management system can achieve its intended outcome(s);

414 — prevent, or reduce, undesired effects, including the potential for external environmental conditions to
 415 affect the organization;

416 — achieve continual improvement.

417 The organization shall maintain documented information of the risk associated with threats and opportunities
418 that needs to be addressed.

419 **6.1.5 Planning to take action**

420 The organization shall plan:

- 421 a) to take actions to address risk associated with threats and opportunities (see 6.1.4), significant
422 environmental aspects (see 6.1.2) and compliance obligations (see 6.1.3);
- 423 b) how to:
 - 424 — integrate and implement the actions into its environmental management system processes;
 - 425 — evaluate the effectiveness of these actions.

426 **6.2 Environmental objectives and planning to achieve them**

427 **6.2.1 Environmental objectives**

428 The organization shall establish environmental objectives at relevant functions and levels:

- 429 — taking into account the organization's significant environmental aspects and its compliance obligations;
- 430 — considering the risk associated with threats and opportunities.

431 When developing these objectives, the organization shall consider its technological options and financial,
432 operational and business requirements.

433 The environmental objectives shall:

- 434 be consistent with the environmental policy;
- 435 a) be measurable (if practicable);
- 436 b) be monitored;
- 437 c) be communicated;
- 438 d) be updated as appropriate.

439 The organization shall retain documented information on the environmental objectives.

440 **6.2.2 Planning actions to achieve environmental objectives**

441 When planning how to achieve its environmental objectives, the organization shall determine:

- 442 — what will be done;
- 443 — what resources will be required;
- 444 — who will be responsible;
- 445 — when it will be completed;
- 446 — how the results will be evaluated, including indicators for monitoring progress toward achievement of
447 measurable environmental objectives (see 9.1.1).

448 The organization shall consider how the actions to achieve environmental objectives can be integrated into the
 449 organization's business processes.

450 **7 Support**

451 **7.1 Resources**

452 The organization shall determine and provide the resources needed for the establishment, implementation,
 453 maintenance and continual improvement of the environmental management system.

454 **7.2 Competence**

455 The organization shall:

- 456 — determine the necessary competence of person(s) doing work under its control that affects its
 457 environmental performance;
- 458 — ensure that these persons are competent on the basis of appropriate education, training, or experience;
- 459 — where applicable, take actions to acquire the necessary competence, and evaluate the effectiveness of
 460 the actions taken.

461 NOTE Applicable actions can include, for example, the provision of training to, the mentoring of, or the re-assignment
 462 of currently employed persons; or the hiring or contracting of competent persons.

463 The organization shall retain appropriate documented information as evidence of competence.

464 **7.3 Awareness**

465 Persons doing work under the organization's control shall be aware of:

- 466 — the environmental policy;
- 467 — the significant environmental aspects and related actual or potential impacts associated with their work;
- 468 — their contribution to the effectiveness of the environmental management system, including the benefits of
 469 enhanced environmental performance;
- 470 — the implications of not conforming with the environmental management system requirements including
 471 compliance obligations.

472 **7.4 Communication**

473 **7.4.1 General**

474 The organization shall plan and implement a process for internal and external communications relevant to the
 475 environmental management system, including:

- 476 — on what it will communicate;
- 477 — when to communicate;
- 478 — with whom to communicate;
- 479 — how to communicate.

480 When planning its communications process, the organization shall:

481 — take into account its compliance obligations;

482 — ensure that environmental information communicated is consistent with information generated within the
483 environmental management system, and is reliable.

484 The organization shall respond to relevant communications on its environmental management system.

485 The organization shall retain documented information as evidence of its communications, as appropriate.

486 **7.4.2 Internal communication**

487 With regard to its environmental management system, the organization shall:

488 a) communicate among the various levels and functions of the organization, including changes to the
489 environmental management system, as appropriate;

490 b) ensure its communication process enables any person doing work under the organization's control to
491 contribute to continual improvement.

492 **7.4.3 External communication**

493 The organization shall externally communicate information relevant to the environmental management
494 system, as determined by its communication process and as required by its compliance obligations.

495 **7.5 Documented information**

496 **7.5.1 General**

497 The organization's environmental management system shall include:

498 a) documented information required by this International Standard;

499 b) documented information determined by the organization as being necessary for the effectiveness of the
500 environmental management system.

501 NOTE The extent of documented information for an environmental management system can differ from one
502 organization to another due to:

503 — the size of organization and its type of activities, processes, products and services;

504 — the complexity of processes and their interactions;

505 — the competence of persons.

506 **7.5.2 Creating and updating**

507 When creating and updating documented information the organization shall ensure appropriate:

508 — identification and description (e.g. a title, date, author, or reference number);

509 — format (e.g. language, software version, graphics) and media (e.g. paper, electronic);

510 — review and approval for suitability and adequacy.

511 7.5.3 Control of documented information

512 Documented information required by the environmental management system and by this International
513 Standard shall be controlled to ensure:

514 a) it is available and suitable for use, where and when it is needed;

515 b) it is adequately protected (e.g. from loss of confidentiality, improper use, or loss of integrity).

516 For the control of documented information, the organization shall address the following activities, as
517 applicable:

518 — distribution, access, retrieval and use;

519 — storage and preservation, including preservation of legibility;

520 — control of changes (e.g. version control);

521 — retention and disposition.

522 Documented information of external origin determined by the organization to be necessary for the planning
523 and operation of the environmental management system shall be identified, as appropriate, and controlled.

524 NOTE Access can imply a decision regarding the permission to [review](#) the documented information only, or the
525 permission and authority to view and change the documented information.

526 8 Operation

527 8.1 Operational planning and control

528 The organization shall plan, implement and control the processes needed to meet [environmental management](#)
529 [system](#) requirements, and to implement the actions determined in 6.1 [and 6.2](#), by:

530 — establishing criteria for the processes;

531 — implementing control of the processes, in accordance with the criteria [and to prevent deviation from the](#)
532 [environmental policy, environmental objectives and compliance obligations](#).

533 NOTE Controls can include engineering controls, procedures, documented procedure, etc. They can be implemented
534 following a hierarchy (e.g. elimination, substitution, administrative) and can be used singly or in combination.

535 The organization shall control planned changes and review the consequences of unintended changes, taking
536 action to mitigate any adverse effects, as necessary.

537 The organization shall ensure that outsourced processes are controlled [or influenced](#). The type and degree of
538 [control or influence to be applied to these processes shall be defined within the environmental management](#)
539 [system](#).

540 [Consistent with a life cycle perspective, the organization shall:](#)

541 a) [determine environmental requirements for the procurement of products and services, as appropriate;](#)

542 b) [establish controls to ensure that environmental requirements are considered in the design process for the](#)
543 [development, delivery, use and end-of-life treatment of its products and services, as appropriate;](#)

544 c) [communicate relevant environmental requirement\(s\) to external providers, including contractors;](#)

- 545 d) consider the need to provide information about potential significant environmental impacts during the
546 delivery of the products or services and during use and end-of-life treatment of the product.

547 The organization shall maintain documented information to the extent necessary to have confidence that the
548 processes have been carried out as planned.

549 8.2 Emergency preparedness and response

550 The organization shall establish and implement a procedure specifying how it will respond to potential
551 environmental emergency situations and potential accidents.

552 The organization shall:

- 553 a) respond to actual emergency situations and accidents;
- 554 b) take action to reduce the consequences of environmental emergency situations, appropriate to the
555 magnitude of the emergency or accident and the potential environmental impact;
- 556 c) take action to prevent the occurrence of environmental emergency situations and accidents;
- 557 d) periodically test the procedure where practicable;
- 558 e) periodically review and, where necessary, revise the procedure, in particular, after the occurrence of
559 accidents, emergency situations or tests.

560 9 Performance evaluation

561 9.1 Monitoring, measurement, analysis and evaluation

562 9.1.1 General

563 The organization shall determine:

- 564 — what needs to be monitored and measured, related to:
- 565 1) its operations that can have a significant environmental impact;
- 566 2) its compliance obligations;
- 567 3) operational controls;
- 568 4) progress towards the organization's environmental objectives, using indicators;
- 569 — the methods for monitoring, measurement, analysis and evaluation, as applicable, to ensure valid results;
- 570 — the criteria against which the organization will evaluate its environmental performance, using appropriate
571 indicators;
- 572 — when the monitoring and measuring shall be performed;
- 573 — when the results from monitoring and measurement shall be analysed and evaluated.

574 The organization shall ensure that calibrated or verified monitoring and measurement equipment is used and
575 maintained as appropriate.

576 The organization shall evaluate its environmental performance and provide input to the management review
577 (see 9.3) for the evaluation of the effectiveness of the environmental management system.

578 The organization shall retain appropriate documented information as evidence of the monitoring,
579 measurement, analysis and evaluation results.

580 The organization shall communicate information relevant to its environmental performance both internally and
581 externally, as determined by its communication process and as required by its compliance obligations.

582 9.1.2 Evaluation of compliance

583 The organization shall plan and implement a process to evaluate conformity with its compliance obligations.

584 The organization shall:

585 — determine the frequency that compliance will be evaluated;

586 — evaluate compliance and take action if needed;

587 — maintain knowledge and understanding of its status of conforming with compliance obligations.

588 The organization shall retain documented information as evidence of the compliance evaluation result(s).

589 9.2 Internal audit

590 9.2.1 The organization shall conduct internal audits at planned intervals to provide information on whether
591 the environmental management system:

592 a) conforms to:

593 — the organization's own requirements for its environmental management system;

594 — the requirements of this International Standard;

595 b) is effectively implemented and maintained.

596 9.2.2 The organization shall:

597 a) plan, establish, implement and maintain an audit programme(s), including the frequency, methods,
598 responsibilities, planning requirements and reporting, which shall take into consideration the
599 environmental importance of the processes concerned, risk associated with threats and opportunities and
600 the results of previous audits;

601 b) define the audit criteria and scope for each audit;

602 c) select auditors and conduct audits to ensure objectivity and the impartiality of the audit process;

603 d) ensure that the results of the audits are reported to relevant management.

604 The organization shall retain documented information as evidence of the implementation of the audit
605 programme and the audit results.

606 9.3 Management review

607 Top management shall review the organization's environmental management system, at planned intervals, to
608 ensure its continuing suitability, adequacy and effectiveness.

609 The management review shall include consideration of:

610 a) the status of actions from previous management reviews;

- 611 b) changes in:
- 612 — external and internal issues that are relevant to the environmental management system;
 - 613 — compliance obligations;
 - 614 — its significant environmental aspects and risk associated with threats and opportunities;
- 615 c) the extent to which objectives have been met;
- 616 d) information on the organization's environmental performance, including trends in:
- 617 — nonconformities and corrective actions;
 - 618 — monitoring and measurement results;
 - 619 — conformity to its compliance obligations;
 - 620 — audit results;
- 621 e) communication(s) from external interested parties;
- 622 f) opportunities for continual improvement;
- 623 g) the adequacy of resources required for maintaining an effective environmental management system.
- 624 The outputs of the management review shall include:
- 625 — conclusions on the continuing suitability, adequacy and effectiveness of the environmental management system;
 - 626 — decisions related to continual improvement opportunities;
 - 627 — any need for changes to the environmental management system, including resource needs;
 - 628 — actions if needed, when objectives have not been met;
 - 629 — any implications for the strategic direction of the organization.
- 630 — any implications for the strategic direction of the organization.
- 631 The organization shall retain documented information as evidence of the results of management reviews.

632 10 Improvement

633 10.1 Nonconformity and corrective action

634 When a nonconformity occurs, the organization shall:

- 635 a) react to the nonconformity and, as applicable:
- 636 — take immediate action to control and correct it;
 - 637 — mitigate adverse environmental impacts;
 - 638 — deal with the consequences;

639 b) evaluate the need for action to eliminate the causes of the nonconformity, in order that it does not recur or
640 occur elsewhere, by:

641 — reviewing the nonconformity;

642 — determining the causes of the nonconformity;

643 — determining if similar nonconformities exist, or could potentially occur;

644 c) **determine and** implement any **corrective** action needed;

645 d) review the effectiveness of any corrective action taken;

646 e) make changes to the environmental management system, if necessary.

647 Corrective actions shall be appropriate to **the significance of** the effects of the nonconformities encountered,
648 **including the environmental impact(s)**.

649 The organization shall retain documented information as evidence of:

650 — the nature of the nonconformities and any subsequent actions taken;

651 — the results of any corrective action.

652 **10.2 Continual improvement**

653 The organization shall continually improve the suitability, adequacy and effectiveness of the environmental
654 management system **to enhance environmental performance**.

Annex A (informative)

Guidance on the use of this International Standard

A.0 General

This International Standard outlines the requirements of a robust, credible and reliable environmental management system. The additional text given in this Annex is strictly informative and is intended to prevent misinterpretation of the requirements contained in this International Standard. While this information addresses and is consistent with these requirements, it is not intended to add to, subtract from, or in any way modify them.

The user should not read a particular sentence or clause of this International Standard in isolation from other clauses of the standard. There is an interrelationship between the requirements in some clauses with the requirements in other clauses.

A.1 Scope

This International Standard does not contain explanatory information on Clause 1.

A.2 Normative references

This International Standard does not contain explanatory information on Clause 2.

A.3 Terms and definitions

The terms that are defined in Clause 3 have a specialized technical meaning and are normative for use in this International Standard. This sub-clause provides further explanation of some of the words that are commonly used in management system standards, to help the user understand their implications and to help in translations.

— 'Programme': planned series of steps, projects or activities to be carried out.

— 'Design': working out the form, fit or function of something.

— 'Purpose': anticipated (intended or expected) outcome that guides planned actions.

— 'Determine': establish or find out.

— 'Define': state or describe exactly the nature, scope or meaning of that which is under consideration.

— 'Identify': establish the identity of something.

To avoid misunderstanding, clarifications of selected concepts are provided below.

— '*NOTES*' included in the various clauses of this International Standard are informative.

— '*Continual*' indicates duration that occurs over a period of time, but with intervals of interruption (unlike '*continuous*' which indicates duration without interruption). '*Continual*' is therefore the appropriate word to use in the context of improvement.

689 — The word '*consider*' means it is necessary to think about but can be rejected; and '*take into account*'
 690 means it is necessary to think about but cannot be rejected.

691 — The words '*appropriate*' and '*applicable*' are not interchangeable. '*Appropriate*' means suitable (for, to)
 692 and implies some degree of freedom, while '*applicable*' means relevant or possible to apply and implies
 693 that if it can be done, it should be done.

694 — This International Standard uses the term '*interested party*', the term '*stakeholder*' is a synonym as it
 695 represents the same concept.

696 — The word '*ensure*' means the responsibility can be delegated, but not the accountability to make sure that
 697 it is performed.

698 This International Standard uses some new terminology. A brief explanation is given below to aid both new
 699 users and those who have used prior editions of this International Standard.

700 — '*Documented information*' replaces the nouns '*documentation*' and '*record*' used in prior editions of this
 701 International Standard. To distinguish the intent of the generic term '*documented information*', this
 702 International Standard now uses the phrase '*retain documented information as evidence of...*' to mean
 703 records, and '*maintain documented information*' to mean documentation other than records. The phrase
 704 "*as evidence of...*" is not a requirement to meet legal evidentiary requirements; its intent is only to
 705 indicate objective evidence needs to be retained.

706 — The change from '*identify*' to '*determine*' is intended to harmonize with the standardized management
 707 system terminology, not to change the intent of the previous edition of this International Standard. The
 708 term '*determine*' implies a discovery process that results in knowledge.

709 — The term '*intended outcome*' means what the organization intends to achieve by implementing its
 710 environmental management system, which includes enhancement of environmental performance,
 711 conformance to compliance obligations and fulfilment of environmental objectives. These are the minimal,
 712 core outcomes, and organizations can set additional intended outcomes for their environmental
 713 management system.

714 — The phrase '*compliance obligations*' replaces the phrase '*legal requirements and other requirements to*
 715 *which the organization subscribes*' used in prior editions of this International Standard. The change is
 716 considered simpler to understand, and does not change the intent of the previous edition of this
 717 International Standard.

718 — The use of the word '*any*' implies selection and choice.

719 **A.4 Context of the organization**

720 **A.4.1 Understanding the context of the organization**

721 The intent of 4.1 is to provide a high-level, conceptual understanding of the important issues that can affect,
 722 either positively or negatively, the way the organization manages its environmental responsibilities. Issues are
 723 important topics for the organization, problems for debate and discussion or changing circumstances that
 724 affect the organization's ability to achieve the intended outcomes it sets for its environmental management
 725 system.

726 Internal and external Issues relevant to the organization's context may include, but are not limited to:

- 727 a) environmental conditions related to climate, air quality, water quality, land use, existing contamination,
 728 natural resource availability, biodiversity, etc., that can either affect the organization's purpose, or be
 729 affected by its environmental aspects;

b) the external cultural, social, political, legal, regulatory, financial, technological, economic, natural and competitive context, whether international, national, regional or local;

c) the internal characteristics or conditions of the organization, such as its activities, products and services, strategic direction, culture and capabilities (people, knowledge, processes, systems).

An understanding of an organization's context results in knowledge that is used to guide its efforts to establish, implement, maintain and continually improve its environmental management system (see 4.4). The internal and external issues that give rise to risk associated with threats and opportunities to the organization or to the environmental management system (see 6.1.4) need to be addressed (see 6.1.5) and managed (see 6.2, 8.1, 8.2 and 9.1).

This organization may document its knowledge of the organization's context, as appropriate.

A.4.2 Understanding the needs and expectations of interested parties

An organization is expected to gain a general (i.e., high-level, not detailed) understanding of the expressed needs and expectations of those internal and external interested parties that have been determined to be relevant so that the knowledge gained can be considered when determining its compliance obligations.

The organization is expected to consider known needs and expectations of interested parties in order to determine those that are relevant. In the case of an interested party perceiving itself to be affected by the organization's decisions or activities related to environmental performance, the organization considers the relevant needs and expectations that have been in some way expressed or disclosed by the party to the organization.

Interested party requirements are not necessarily requirements of the organization. Some interested party requirements reflect needs and expectations that are mandatory because they have been incorporated into laws, regulations, permits and licenses by governmental or even court decision. Others the organization may decide to voluntarily agree to or adopt, (e.g. entering into a contractual relationship, or subscribing to a voluntary initiative). Once the organization adopts them, then they become organizational requirements, i.e. compliance obligations, and are taken into account when planning for the environmental management system (see 4.4). A more detailed-level analysis of its compliance obligations is performed in 6.1.3.

The organization may document its knowledge of relevant interested party requirements, as appropriate.

A.4.3 Scope of the environmental management system

The scope of the environmental management system is intended to clarify the spatial and organizational boundaries to which the environmental management system will apply, especially if the organization is a part of a larger organization at a given location. An organization has the freedom and flexibility to define its boundaries. It may choose to implement this International Standard with respect to the entire organization, or to (a) specific part(s) of the organization, as long as the top management of that part of the organization has authority for establishing an environmental management system.

In setting the scope, the credibility of the environmental management system will depend upon the choice of organizational boundaries. The organization considers the degree of control or influence that it can exert over activities, products and services considering a life cycle perspective. Scoping should not be used to exclude activities, products, services, or facilities that have or can have significant environmental aspects, or to evade its compliance obligations. The scope should be factual and representative of the organization's operations included within its environmental management system boundaries so that it does not mislead interested parties.

Once the organization asserts it conforms to this International Standard, the scope is made available to interested parties.

773 **A.4.4 Environmental management system**

774 The organization retains authority, accountability, and autonomy, to decide how it will fulfil the requirements of
775 this International Standard, including the level of detail and extent to which it will:

- 776 — integrate environmental management system requirements into its various business functions, such as
777 design & development, procurement, human resources, sales and marketing, etc.;
- 778 — incorporate issues associated with its context (see 4.1) and interested party requirements (see 4.2) within
779 its environmental management system.

780 If this International Standard is implemented for (a) specific part(s) of an organization, policies and procedures
781 developed by other parts of the organization can be used to meet the requirements of this International
782 Standard, provided that they are applicable to the specific part(s) that will be subject to them.

783 **A.5 Leadership**

784 **A.5.1 Leadership and commitment**

785 Commitment and active support, including providing adequate resources, from the organization's top
786 management are critical for the success of the environmental management system.

787 5.1 specifies actions in which top management is personally involved with and directs in the organization. Top
788 management may not perform all of these actions themselves (e.g. they may delegate responsibility to
789 others), but they are accountable for ensuring that they are performed.

790 Top management is expected to create a culture and environment that encourages people in leadership roles
791 (not necessarily formal management positions, e.g. team leaders) to work actively towards implementing the
792 requirements of the environmental management system and fulfilling the environmental objectives.

793 **A.5.2 Environmental policy**

794 The environmental policy is a set of principles stated as commitments in which top management outlines the
795 long-term direction of the organization to support and enhance its environmental performance. The
796 environmental policy enables the organization to set its objectives and take actions to achieve the intended
797 outcomes of the environmental management system.

798 5.2 specifies three basic commitments for the environmental policy: to protect the environment, to conform to
799 the organization's compliance obligations and to continual improvement. These commitments are then
800 addressed in specific requirements in other clauses to establish, implement, maintain and continually improve
801 a robust, credible and reliable environmental management system.

802 The commitment to protect the environment is intended to not only prevent adverse environmental impacts,
803 but to protect the natural environment from harm and degradation. The specific commitment(s) an
804 organization pursues should be relevant to its context and positively affect the local or regional environmental
805 conditions. These commitments may address water quality, recycling, or air quality and may also include far
806 broader opportunities related to climate change mitigation and adaptation, preservation of biodiversity and
807 ecosystems, and restoration.

808 It is important to understand that the requirements in this International Standard need to be viewed from a
809 systems or holistic perspective. This means that the organization needs to have an appreciation for the
810 relationship between the policy commitments and the requirements that are specified in other clauses.

811 While all the commitments are important, some interested parties are especially concerned with the
812 organization's commitment to conform to its compliance obligations, particularly the need for the organization
813 to meet applicable legal requirements. In this respect it is important to acknowledge that this International
814 Standard specifies a number of interconnected requirements related to this commitment. This includes the

need to determine compliance obligations, to ensure operations are carried out in accordance with these compliance obligations and to evaluate conformity with the compliance obligations.

The organization's reputation and the credibility of its environmental management system are dependent on its success in meeting and when possible, exceeding all of its policy commitments.

A.5.3 Organizational roles, responsibilities and authorities

Person(s) assigned these roles by top management should have sufficient access to top management in order to ensure the participation of top management in case of critical situations related to the establishment, implementation, maintenance and continual improvement of the environmental management system. The role of and authority for reporting on the performance of the environmental management system is often assigned to (a) management representative(s).

A.6 Planning

A.6.1 Actions to address risk associated with threats and opportunities

A.6.1.1 General

The context of the organization (see 4.1 and 4.2) provides an overarching framework for evaluating the risk associated with threats and opportunities in 6.1. It provides a basis for:

- a) identifying environmental aspects and for establishing criteria for determining those that may be significant;
- b) determining compliance obligations and understanding how they apply to the organization's activities, products and services; and
- c) establishing criteria for evaluating risk associated with threats and opportunities.

Issues identified when considering the organization's context, its significant environmental aspects or its compliance obligations and their associated threats and opportunities are to be taken into account in establishing, implementing maintaining and continually improving the organization's environmental management system.

It is up to the organization to determine the nature and level of detail of the documented information it develops.

A.6.1.2 Significant environmental aspects

6.1.2 sets out the process(es) an organization should use to identify its environmental aspects and associated impacts, and to determine those that are significant which should be addressed as a priority by the organization's environmental management system.

Changes to the environment, either adverse or beneficial, that result wholly or partially from environmental aspects are called environmental impacts. The environmental impact may occur at local, regional and global scales, while they may also be direct, indirect or cumulative by nature. The relationship between environmental aspects and environmental impacts is one of cause and effect.

In the identification of environmental aspects the organization should apply a life cycle perspective. However, this does not require a detailed life cycle assessment; a simple consideration of the life cycle stages which can be controlled or influenced by the organization is sufficient. For this purpose the organization may obtain this information directly or seek it from the supplier of the products and services. Information already developed for regulatory or other purposes may be used in this process. Typical stages of a product life cycle can include, for example, extraction of raw materials, design, production, transportation, use, and end-of-life treatment. The life cycle stages that are applicable will vary depending on the activity, product or service.

856 An organization should identify the environmental aspects within the scope of its environmental management
 857 system, taking into account the inputs and outputs (both intended and unintended) associated with its current
 858 and relevant-past activities, products and services, planned or new developments, or new or modified
 859 activities, products and services.

860 An emergency situation can be considered an undesired event that, if not addressed, could ultimately lead to
 861 adverse consequences to the organization or the environment, as determined and prioritized during the
 862 environmental management system planning stage. The process of environmental aspects identification
 863 includes identification of normal and abnormal operating conditions, shut-down and start-up conditions, as well
 864 as reasonably foreseeable emergency situations. Special attention should be paid to prior occurrences of
 865 emergency situations, and results from testing emergency response procedures.

866 Organizations do not have to consider each product, component or raw material individually, and may select
 867 categories of activities, products and services to identify and evaluate their environmental aspects, when they
 868 can be managed in a common way.

869 Although there is no single approach for identifying environmental aspects, the approach selected could for
 870 example include:

- 871 a) emissions to air;
- 872 b) releases to water;
- 873 c) releases to land;
- 874 d) use of raw materials and natural resources;
- 875 e) use of energy;
- 876 f) energy emitted, e.g. heat, radiation, vibration (noise) and light;
- 877 g) generation of waste and/or by-products;
- 878 h) environmental aspects with beneficial impact.

879 In addition to the environmental aspects an organization can control directly, an organization needs to
 880 determine whether there are environmental aspects that it can influence. These can be related to products
 881 and services used by the organization which are provided by others, as well as products and services that it
 882 provides to others outside the organization, including those associated with outsourced processes. With
 883 respect to products and services the organization provides and renders to others, organizations may have
 884 limited influence on the use and final disposal of their products once they leave their control. However, in all
 885 circumstances it is the organization that determines the degree of control it is able to exercise, the
 886 environmental aspects it can influence, and the extent to which it chooses to exercise any such influence.

887 Consideration should be given to environmental aspects related to the organization's activities, products and
 888 services, such as:

- 889 — design and development of its facilities, processes, products and services, including development of
 890 products and services with reduced negative environmental impact;
- 891 — use of raw materials and natural resources;
- 892 — operational or manufacturing processes, including warehousing;
- 893 — operation and maintenance of facilities, organizational assets and infrastructure;
- 894 — environmental performance and practices of contractors and suppliers;

895 — product distribution and service delivery, including packaging and transportation;

896 — storage, use and end-of-life treatment of products;

897 — waste generation, management and disposal, including reuse, refurbishing, recycling.

898 There is no single method for determining significant environmental aspects. However, the method and criteria
899 used should provide consistent results.

900 An environmental aspect can cause an environmental impact therefore it can result in a threat or opportunity
901 that needs to be addressed in order to ensure the organization can achieve the intended outcomes of the
902 environmental management system. An environmental aspect having the potential to cause an adverse
903 impact to the environment can be considered a “threat”, whereas an environmental aspect having the potential
904 to cause a beneficial environmental impact can be considered an “opportunity”.

905 **A.6.1.3 Compliance obligations**

906 The organization needs to determine, at a detailed level, the compliance obligations it identified in 4.2 that are
907 applicable to its environmental aspects and how they apply to the organization. Compliance obligations
908 include legal and other mandatory obligations that the organization is required to comply with, and those
909 obligations which the organization has discretion over whether or not to adopt.

910 Legal obligations are mandatory requirements issued by governmental entities or other relevant authorities.
911 These may include:

912 — law and regulations;

913 — permits, licenses or other forms of authorization;

914 — orders, rules or guidance issued by regulatory agencies;

915 — judgments of courts or administrative tribunals;

916 — treaties, conventions and protocols.

917 Compliance obligations also include other interested party requirements related to its environmental aspects,
918 which the organization chooses to adopt. These may include, if applicable:

919 a) agreements with community groups or non-governmental organizations;

920 b) agreements with public authorities and customers;

921 c) organizational requirements;

922 d) voluntary principles or codes of practice;

923 e) voluntary labelling or environmental commitments;

924 f) obligations arising under contractual arrangements with the organization;

925 g) relevant organizational and industry standards.

926 The primary difference between a legal requirement and a voluntary obligation is that the organization
927 chooses to adhere to its voluntary obligations. However, once that choice is made, adherence becomes
928 mandatory, particularly where legally binding agreements are made.

929 **A.6.1.4 Risk associated with threats and opportunities**

930 Risk associated with threats and opportunities may be related to one or more of an organization's significant
 931 environmental aspects, compliance obligations or other issues, such as those created by external
 932 environmental conditions or by any internal circumstances. The organization determines the risk associated
 933 with threats or opportunities that can affect its ability to achieve the intended outcome of its environmental
 934 management system, prevent or reduce undesired effects or achieve continual improvement, and therefore
 935 needs to be addressed. An organization can determine the risk associated with threats and opportunities
 936 separately or in combination, and can integrate its approach with the analyses in previous sub-clauses (see
 937 6.1.2 and 6.1.3).

938 The organization selects the method by which risk associated with threats and opportunities is determined.
 939 The method may involve a very simple qualitative process or a full quantitative assessment, depending on the
 940 context in which the organization operates (e.g. size of the organization, technological sector, maturity level of
 941 the environmental management system).

942 The results of this determination are the input for planning actions (see 6.1.5) and for establishing the
 943 environmental objectives (see 6.2).

944 **A.6.1.5 Planning to take action**

945 Some of these threats and opportunities, including those created by other issues affecting the organization's
 946 ability to achieve the intended outcomes of the environmental management system, can also be important
 947 inputs for other parts of the management system, such as support (see Clause 7), operation (see Clause 8),
 948 performance evaluation (see Clause 9) and improvement (see Clause 10).

949 The planning may address the actions through a single or combination of pathways within the environmental
 950 management system, including, e.g. setting objectives, operational planning and control, emergency
 951 preparedness or monitoring and measurement.

952 Some actions may be addressed through other business processes such as occupational health and safety or
 953 business continuity management systems, or other processes related to risk, financial or human resource
 954 management.

955 **A.6.2 Environmental objectives and planning to achieve them**

956 Environmental objectives may be established by top management at the strategic level, the tactical level or
 957 the operational level. The strategic level includes the highest levels of the organization and the objectives are
 958 applicable to the whole organization. The tactical and operational levels can include objectives for specific
 959 units or functions within the organization and should be compatible with its strategic direction. The concept of
 960 "target" used in prior editions of this International Standard is captured within the definition of "environmental
 961 objective".

962 While the requirement to "*take into account significant environmental aspects*" does not mean that an
 963 objective has to be established for each significant aspect, it should be clear that significant aspects have a
 964 high priority when developing objectives.

965 "*Consistent with the environmental policy*" means that the environmental objectives need to be broadly aligned
 966 and harmonised with the commitments made by top management in the environmental policy.

967 Indicators are selected to measure the achievement of measurable objectives. By including the caveat '*where*
 968 *practicable*', it is acknowledged that there may be situations when it may not be feasible to measure an
 969 objective. More guidance on setting environmental indicators can be found in ISO 14031.

A.7 Support

A.7.1 Resources

Resources include human resources, natural resources, infrastructure, technology, and financial resources.

Human resources include specialized skills and knowledge. Infrastructure includes the organization's buildings, containment systems, pumps, etc.

A.7.2 Competence

This sub-clause applies to any person(s):

- a) whose work has the potential to cause a significant environmental impact;
- b) who are assigned responsibilities for the environmental management system, including those who:
 - 1) identify and evaluate environmental impacts and compliance obligations;
 - 2) contribute to the achievement of an environmental objective;
 - 3) respond to emergency situations;
 - 4) perform internal audits;
- c) who otherwise affect(s) environmental performance.

A.7.3 Awareness

Awareness of the environmental policy should not be taken to mean that the commitments need to be memorized or that persons doing work under the organization's control have a copy of the actual, documented environmental policy; rather, they should be aware of its existence, the purpose and their role in achieving the commitments.

A.7.4 Communication

Communication allows the organization to provide and obtain information relevant to its environmental management system, including its significant environmental aspects, environmental performance and compliance obligations. The communication process is seen as a two-way process, in and out of the organization.

The information received by the organization may contain requests from interested parties for specific information related to the management of its environmental aspects, and also general impressions or views on the way the organization carries out that management. These views can be either positive or negative in nature. In the latter case (e.g. complaints), it is important a prompt and clear answer is provided by the organization. A subsequent analysis of these complaints can provide valuable information for detecting improvement opportunities for the environmental management system.

In determining how it will communicate, the organization should consider:

- a) methods, including verbal or written;
- b) tools, including internet, letter, video or reports;
- c) who communicates.

Communication should be:

- 1005 — transparent, so the organization is open to the way it derived what it has reported on;
- 1006 — appropriate, so that information meets relevant interested parties' needs, enabling them to participate;
- 1007 — truthful and not misleading those who rely on the information reported;
- 1008 — factual, accurate and reliable, ensured by robust systems and procedures;
- 1009 — complete in its own context and does not exclude relevant information;
- 1010 — clear and understandable to interested parties.
- 1011 When planning, the internal organizational structure should be considered to ensure communication with the
 1012 most appropriate levels and functions. Communication with each person doing work under its control may not
 1013 be needed; a single approach to the whole organization may be adequate to meet the objectives of its
 1014 communication.
- 1015 For additional information on communication see ISO 14063.

1016 **A.7.5 Documented information**

1017 The intent of 7.5 is to ensure that organizations create and maintain documented information in a manner
 1018 sufficient to implement the environmental management system. The primary focus of organizations, however,
 1019 should be on the effective implementation of the environmental management system and on environmental
 1020 performance, not on a complex documented information control system.

1021 Documented information originally created for purposes other than the environmental management system,
 1022 may be used. The documented information for the environmental management system may be integrated with
 1023 other information management systems implemented by the organization. It does not have to be in the form of
 1024 a manual.

1025 **A.8 Operation**

1026 **A.8.1 Operational planning and control**

1027 The types and degrees of operational control depend on the nature of the operations, the significant
 1028 environmental aspects, risk associated with threats and opportunities, and compliance obligations. An
 1029 organization has the flexibility to select the type(s) of operational control methods, singly or in combination,
 1030 necessary to make sure a process is effective in achieving the desired results. Such methods may include:

- 1031 a) designing a process in such a way to prevent error and ensure consistent results;
- 1032 b) using technology to control processes and prevent adverse results (i.e., engineered controls);
- 1033 c) using competent personnel to assure desired results;
- 1034 d) performing the process in a specified way (i.e., procedure);
- 1035 e) monitoring or measuring the process to check the results;
- 1036 f) determining the use and amount of documented information necessary.

1037 Work that is '*under the organization's control*' is work that takes place within the scope of the environmental
 1038 management system.

The organization decides the extent of control needed within its own business processes (e.g., procurement process) to control or influence outsourced processes (see explanation below) or suppliers of products and services, based upon factors such as:

- knowledge, competence and resources, including:
 - the competence of the supplier to meet the requirements of the organization's environmental management system;
 - the technical competence of the organization to define appropriate controls or assess the adequacy of controls;
 - the importance and potential impact on the organization's capability to provide products and services that conform to the intended outcomes of the environmental management system, including the risk of deviation from its environmental policy, objectives, and compliance obligations;
 - the degree to which the control for the process is shared;
 - the capability of achieving the necessary control through the application of its general procurement process;
 - opportunities available.

In the case of work performed via outsourced processes (see explanation below) or supplied products and services, the organization's ability to exert control or influence will vary, from direct control to limited or no influence. For example, an outsourced process performed onsite may be under the direct control of a large organization. Alternatively, the ability of small and medium size organizations to influence an outsourced process or supplier may be limited by their relative size.

An outsourced process is one which:

- the function or process is integral to the organization's functioning;
- the function or process is needed for the management system to achieve its intended outcome;
- liability for the function or process conforming to requirements is retained by the organization; and
- the organization and the external provider have an integral relationship e.g. one where the process is perceived by interested parties as being carried out by the organization.

A.8.2 Emergency preparedness and response

This International Standard does not contain explanatory information on 8.2.

A.9 Performance evaluation

A.9.1 Monitoring, measurement, analysis and evaluation

A.9.1.1 General

In order to ensure that its environmental policy and environmental objectives are achieved, the organization should ensure that:

- a) the results of monitoring and measurement are reliable, reproducible and traceable;
- b) the way in which data resulting from monitoring and measurement are aggregated before any analysis and evaluation takes place is clearly defined and reproducible;

1075 c) the findings of analysis and evaluation of environmental performance are reported internally to those with
1076 responsibility and authority to initiate appropriate action;

1077 d) the information obtained is communicated externally in accordance with compliance obligations.

1078 **A.9.1.2 Evaluation of compliance**

1079 The frequency and timing of evaluations of compliance may vary depending on the importance of the
1080 requirement, variations in operating conditions and the organization's past performance, however all
1081 compliance obligations need to be evaluated.

1082 An organization can use a variety of methods to maintain its knowledge and understanding of its compliance
1083 status, including:

1084 a) facility tours or inspections;

1085 b) direct observations or interviews;

1086 c) project or work reviews;

1087 d) review of sample analyses or test results, and comparison to regulatory limits;

1088 e) verification sampling or testing.

1089 In the event that the results indicate a failure to meet a legal requirement, the organization should determine
1090 and implement the actions necessary to achieve compliance. This may require communication with a
1091 regulatory agency and agreement on a course of action to re-establish compliance with legal requirements.
1092 Where such an agreement is in place, this becomes a compliance obligation.

1093 A non-compliance may not rise to the level of a system nonconformity if, for example, it is identified and
1094 corrected by the environmental management system processes. Further, compliance-related system non-
1095 conformities that are detected must be corrected, even if those nonconformities have not resulted in actual
1096 non-compliance with legal requirements.

1097 **A.9.2 Internal audit**

1098 The management and conduct of internal audits should abide by the principles of integrity, fair presentation,
1099 due professional care, confidentiality, independence and an evidence-based approach.

1100 Auditors should be independent of the activity being audited, wherever practicable, and should in all cases act
1101 in a manner that is free from bias and conflict of interest.

1102 The extent of the audit programme should be based on the size and nature of the organization, as well as the
1103 complexity and level of maturity of the environmental management system.

1104 When considering the environmental importance of the processes concerned in its audit programme, the
1105 organization should include:

1106 a) the plans made and actions taken to address the organization's significant environmental aspects and
1107 compliance obligations;

1108 b) the outputs of its monitoring and measurement processes;

1109 c) previous occurrences of accidents or emergency situations that resulted in or could have resulted in
1110 environmental impacts.

1111 When considering the results of previous audits, the organization should include:

— previously identified nonconformities and the effectiveness of the actions taken;

— results of internal and external audits.

Guidance on establishing an internal audit programme, performing environmental management system audits and evaluating the competence of audit personnel is given in ISO 19011.

A.9.3 Management review

The management review should be high-level; it does not need to be an exhaustive review of the details.

The management review topics need not be addressed all at once; the review may take place over a period of time.

It should be noted that communication(s) from external interested parties include complaints. Therefore, the information submitted for analysis to top management should include the relevant complaints received from interested parties, which may provide direct information that will allow top management to determine opportunities for improvement.

A.10 Improvement

A.10.1 Nonconformity and corrective action

Documented information may include the corrective action taken, the results of corrective action and information on the review of the effectiveness of those actions.

There is no longer a single clause with specific requirements for 'preventive action' because one of the key purposes of an environmental management system is to act as a preventive tool. This concept is now captured in 4.1 (i.e., Understanding the organization and its context) and 6.1 (i.e., Actions to address risk associated with threats and opportunities). In combination, these two sets of requirements are considered to cover the concept of preventive action.

A.10.2 Continual improvement

The rate, extent and timescale of actions that support continual improvement are determined by the organization. Although there may be value in improving the system elements alone, the intended outcome of planned actions and other system changes is an enhancement in the environmental performance of the organization.

Annex B (informative)

Correspondence between ISO/DIS 14001:2014 and ISO 14001:2004

Table B.1 — Correspondence between ISO/DIS 14001:2014 and ISO 14001:2004

ISO/DIS 14001:2014		ISO 14001:2004	
Context of the organization (title only)	4		
Understanding the organization and its context	4.1		
Understanding the needs and expectations of interested parties	4.2		
Determining the scope of the environmental management system	4.3	4.1	General requirements
Environmental management system	4.4	4.1	General requirements
Leadership (title only)	5		
Leadership and commitment	5.1		
Environmental policy	5.2	4.2	Environmental policy
Organizational roles, responsibilities and authorities	5.3	4.4.1	Resources, roles, responsibility and authority
Planning (title only)	6	4.3	Planning (title only)
Actions to address risk associated with threats and opportunities (title only)	6.1		
General	6.1.1		
Significant environmental aspects	6.1.2	4.3.1	Environmental aspects
Compliance obligations	6.1.3	4.3.2	Legal and other requirements
Risk associated with threats and opportunities	6.1.4		
Planning to take action	6.1.5		
Environmental objectives and planning to achieve them (title only)	6.2	4.3.3	Objectives, targets and programme(s)
Environmental objectives	6.2.1	4.3.3	Objectives, targets and programme(s)
Planning actions to achieve environmental objectives	6.2.2	4.3.3	Objectives, targets and programme(s)
Support (title only)	7	4.4	Implementation and operation (title only)
Resources	7.1	4.4.1	Resources, roles, responsibility and authority
Competence	7.2	4.4.2	Competence, training and awareness
Awareness	7.3	4.4.2	Competence, training and awareness
Communication (title only)	7.4	4.4.3	Communication
General	7.4.1	4.4.3	Communication
Internal communication	7.4.2	4.4.3	Communication
External communication	7.4.3	4.4.3	Communication
Documented information (title only)	7.5	4.4.4	Documentation

Table B.1 (continued)

ISO/DIS 14001:2014		ISO 14001:2004	
General	7.5.1	4.4.4	Documentation
Creating and updating	7.5.2	4.4.5	Control of documentation
		4.5.4	Control of records
Control of documented information	7.5.3	4.4.5	Control of documentation
		4.5.4	Control of records
Operation (title only)	8	4.4	Implementation and operation (title only)
Operational planning and control	8.1	4.4.6	Operational control
Emergency preparedness and response	8.2	4.4.7	Emergency preparedness and response
Performance evaluation (title only)	9	4.5	Checking (title only)
Monitoring, measurement, analysis and evaluation (title only)	9.1	4.5.1	Monitoring and measurement
General	9.1.1	4.5.1	Monitoring and measurement
Evaluation of compliance	9.1.2	4.5.2	Evaluation of compliance
Internal audit	9.2	4.5.5	Internal audit
Management review	9.3	4.6	Management review
Improvement (title only)	10		
Nonconformity and corrective action	10.1	4.5.3	Nonconformity, corrective action and preventive action
Continual improvement	10.2		

Table B.2 — Correspondence between ISO 14001:2004 and ISO/DIS 14001:2014

ISO 14001:2004		ISO/DIS 14001:2014	
		4	Context of the organization (title only)
		4.1	Understanding the organization and its context
		4.2	Understanding the needs and expectations of interested parties
Environmental management system requirements (title only)	4		
General requirements	4.1	4.3	Determining the scope of the environmental management system
		4.4	Environmental management system
		5	Leadership (title only)
		5.1	Leadership and commitment
Environmental policy	4.2	5.2	Environmental policy
Planning (title only)	4.3	6	Planning (title only)
		6.1	Actions to address risk associated with threats and opportunities (title only)
		6.1.1	General
Environmental aspects	4.3.1	6.1.2	Significant environmental aspects
Legal and other requirements	4.3.2	6.1.3	Compliance obligations
		6.1.4	Risk associated with threats and opportunities
		6.1.5	Planning to take action
Objectives, targets and programme(s)	4.3.3	6.2	Environmental objectives and planning to achieve them (title only)
		6.2.1	Environmental objectives
		6.2.2	Planning actions to achieve environmental objectives

Table B.2 (continued)

ISO 14001:2004		ISO/DIS 14001:2014	
Implementation and operation (title only)	4.4	7	Support (title only)
		8	Operation (title only)
Resources, roles, responsibility and authority	4.4.1	7.1	Resources
		5.3	Organizational roles, responsibilities and authorities
Competence, training and awareness	4.4.2	7.2	Competence
		7.3	Awareness
Communication	4.4.3	7.4	Communication (title only)
		7.4.1	General
		7.4.2	Internal communication
		7.4.3	External communication
Documentation	4.4.4	7.5	Documented information (title only)
		7.5.1	General
Control of documentation	4.4.5	7.5.2	Creating and updating
		7.5.3	Control of documented information
Operational control	4.4.6	8.1	Operational planning and control
Emergency preparedness and response	4.4.7	8.2	Emergency preparedness and response
Checking (title only)	4.5	9	Performance evaluation (title only)
Monitoring and measurement	4.5.1	9.1	Monitoring, measurement, analysis and evaluation (title only)
		9.1.1	General
Evaluation of compliance	4.5.2	9.1.2	Evaluation of compliance
Nonconformity, corrective action and preventive action	4.5.3	10.1	Nonconformity and corrective action
Control of records	4.5.4	7.5.2	Creating and updating
		7.5.3	Control of documented information
Internal audit	4.5.5	9.2	Internal audit
Management review	4.6	9.3	Management review
		10	Improvement (title only)
		10.2	Continual improvement

Annex C (informative)

Alphabetical index of terms in Clause 3

The list in this Annex will be ordered according to the alphabetical order in the language into which this International Standard is translated.

- audit** 3.28
- competence** 3.19
- compliance obligation** 3.22
- conformity** 3.23
- continual improvement** 3.29
- corrective action** 3.25
- documented information** 3.7
- effectiveness** 3.20
- environment** 3.8
- environmental aspect** 3.9
- environmental condition** 3.11
- environmental impact** 3.10
- environmental management system** 3.4
- environmental objective** 3.17
- environmental performance** 3.13
- environmental policy** 3.6
- indicator** 3.33
- interested party** 3.5
- life cycle** 3.15
- management system** 3.3
- measurement** 3.27
- monitoring** 3.31
- nonconformity** 3.24
- objective** 3.16
- organization** 3.1
- outsource** (verb) 3.32
- performance** 3.12
- prevention of pollution** 3.14
- procedure** 3.30
- process** 3.26
- requirement** 3.21
- risk** 3.18
- top management** 3.2

1190

Bibliography

- 1191 ISO 14004, *Environmental management systems — General guidelines on principles, systems and support*
1192 *techniques*
- 1193 ISO 14031, *Environmental management — Environmental performance evaluation — Guidelines*
- 1194 ISO 14044, *Environmental management — Life cycle assessment — Requirements and guidelines*
- 1195 ISO 14063, *Environmental management — Environmental communication — Guidelines and examples*
- 1196 ISO 19011, *Guidelines for auditing management systems*
- 1197 ISO/IEC Guide 73, *Risk management. Vocabulary. Guidelines for use in standards*